

CLOSE TO KILL:
VESTIGIAL TECHNOLOGIES AND COMBAT ARMS

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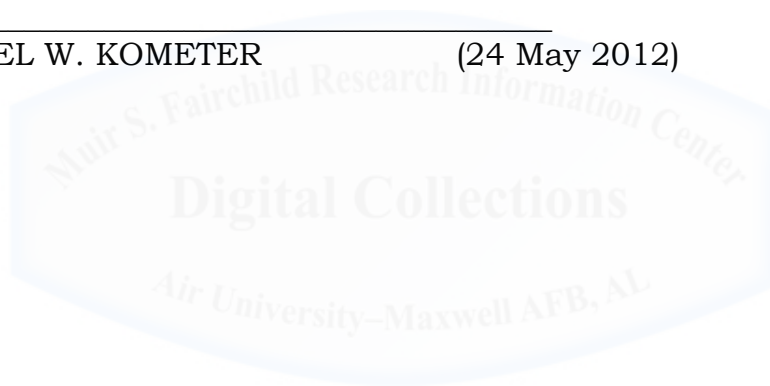
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DISCLAIMER

The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, Department of Defense, the United States Air Force, or Air University.



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ABSTRACT

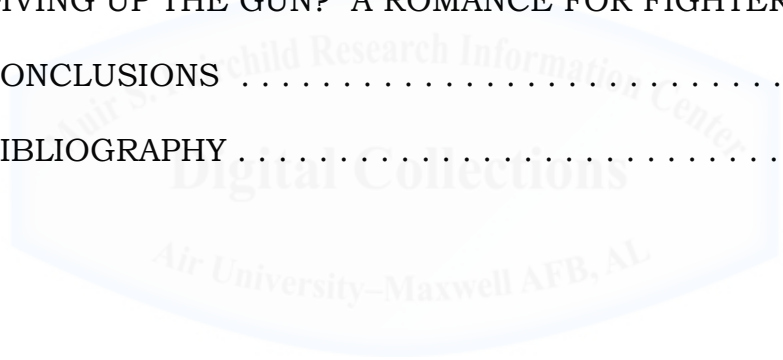
Closing with the enemy is a primal instinct somewhat antithetical to the trajectory of technological development, which has generally permitted killing at greater distances. The mere thought of ramming a several-thousand-ton ship into another vessel, stabbing a blade into the chest of an adversary, or achieving the much vaunted air-to-air guns kill is likely to raise one's heart rate. Actually mentioning these words in today's military environment quickly invites heated debate concerning the material and psychological dimensions of warfare.

This study analyzes the history of the naval ram, bayonet, and internal gun in fighter aircraft. Two periods of time are explored for each technology. Costs and benefits are evaluated during the periods of time the technologies were preeminent in combat. The technologies are also examined in the aftermath of their fall from primacy.

This study concludes the value of *vestigial*, close-to-kill technologies hinges on addressing five themes. The themes include: the quality of long range technologies, number of standoff effects available, likelihood of encountering an enemy in close quarters, expenses associated with the vestigial weapon, and unintended costs and benefits. Under the lens of these themes, analyses of the ram for ships, bayonet for infantry rifles, and internal gun for fighter aircraft suggest psychological and social costs and benefits are more relevant to their value than material factors. Consequently, as it is often difficult and time-consuming to assess and evaluate such ill-defined justifications, leaders should dig deeper before dismissing a weapon based on face value.

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Introduction

On 24 October 1967 Major William T. Kirk was credited with a coveted MIG kill in skies over enemy territory in North Vietnam.¹ He scored the victory while in support of the first bombing raid on the Phuc Yen airfield.² His task for the mission was to provide top cover for a number of bomb-equipped F-105s and F-4s flying from Takhli Royal Thai Air Force Base, Thailand. Major Kirk's kill happened after his formation intercepted a MIG-21 attacking the fighter-bombers en route to the target. His victory was neither the first nor the last of its kind.

Major Kirk's story is not an unusual tale for his time and place in history. However, what is unique about his experience is how he achieved his aerial accomplishment. During a long, ten-minute engagement with the MIG, Major Kirk fired a full load of six air-to-air missiles at his adversary.³ Unfortunately, as none of the missiles found their intended target, he was forced to maneuver into gun range and deliver the final coup de grâce with what many at the time considered a vestigial, close-to-kill technology.⁴ The use of the gun, a podded version of the one that had been removed from aircraft following the Korean War, led to Maj Kirk's kill.⁵

Questions

Stepping back, we see Major Kirk's gun-kill highlights a number of questions with regard to killing technologies. For example, what would he have done if he had not had a gun pod? Based on the low probability

¹ 433rd Tactical Fighter Squadron History: 1 Oct 67 – 31 Dec 67, in 8th Tactical Fighter Wing History: Oct – Dec 1967, Call # K-WG-8-HI, Vol I, pp. 9-10, IRIS # 00447611, USAF Collection, AFHRA, Maxwell AFB AL. Information is now declassified.

² 433rd Tactical Fighter Squadron History: 1 Oct 67 – 31 Dec 67, 9-10.

³ 433rd Tactical Fighter Squadron History: 1 Oct 67 – 31 Dec 67, 10.

⁴ 433rd Tactical Fighter Squadron History: 1 Oct 67 – 31 Dec 67, 10.

⁵ Major Kirk was using likely using a SUU-16A gun pod. The 8th Tactical Fighter Wing did not upgrade to the SUU-23A gun pod until January-March 1968. 433rd Tactical Fighter Squadron History: 1 Jan 68 – 31 Mar 68, in 8th Tactical Fighter Wing History: Jan – Mar 1968, Call # K-WG-8-HI, Vol I, p. 68, IRIS # 00447613, USAF Collection, AFHRA, Maxwell AFB AL. Information is now declassified.

of a missile hitting its target, would he have even initiated or continued to engage in a drawn-out “dog fight?” Would his calculus have been different had he a monopoly on the element of surprise or speed and maneuver? What if there was no requirement for Major Kirk to be in the cockpit to begin with? What if his aircraft had been remotely piloted? Would there still have been a need for a gun? As one can see, the questions surrounding killing technologies are complex affairs.

This thesis attempts to answer the above questions and more. Specifically, it endeavors to determine the *value of vestigial, close-to-kill technologies*; or close-in weapons whose primacy appears to have passed. Furthermore, it seeks to answer the question, are they cost-effective? While the answer in the above anecdote is clearly yes, results are often less clearly defined, especially with lives and the security of the nation in the balance.

Why Important

Navies, armies, and air forces have all embraced technologies long after their primacy appears to have been superseded by newer methods exercised over greater distance. A navy’s passion for the ram, and an army’s for the bayonet, are perhaps exceeded only by air forces’ obsession with the machine gun. Retaining vestigial technologies comes with costs, ranging from lost opportunities to increased risks to human lives. During fiscally constrained times, all branches of the military are asked to do “more with less.” Understanding the costs and benefits of close-to-kill technologies, specifically those related to psychology, sociology, and unintended consequences, may provide insight for military decision-makers in acquisition, training, and force structure. Enhanced objectivity in these areas, in turn, translates to more effective military strategy.

Methodology

This study analyzes the naval ram, bayonet, and internal gun in fighter aircraft. The ram highlights a technology that has played out its

life cycle in naval affairs. The bayonet encompasses a technology with two faces; although it remains an icon for the US Marine Corps, it has been dismissed by the Army. The internal gun is still embraced by the US Air Force for its fifth generation fighters. Two periods of time are explored for each technology. Costs and benefits are evaluated during the periods when the technologies were preeminent in combat. The technologies are also examined in the aftermath of their fall from primacy. The cost-benefit analyses will address factors related to equipping and sustaining military forces in addition to peacetime and wartime employment. Each case study concludes with an overall estimate of the value of the technology. A final, summative conclusion will attempt to answer the above questions, highlight trends, and promote a method of analysis for engaging vestigial-technology-based decisions.



Chapter 1

The Naval Ram

I am going to ram the Cumberland. I'm told she has the new rifled guns, the only ones in their whole fleet we have cause to fear. The moment we are in the Roads I'm going to make right for her and ram her.

*Captain Franklin Buchanan
CSS Virginia*

The history of the naval ram is both extensive and intriguing. Whereas most military technologies go through a single lifecycle, the naval ram experienced two. During the age of oared power, groups of men translated the might of their bodies into crushing blows through the use of wooden and bronze protrusions extending from the bows of their vessels. However, with the inception of the sail, sailors were no longer able to effectively achieve their objectives by use of the ram and consequently abandoned the concept. As steam power came to the forefront of naval affairs, the ram once again captured the attention of the world's naval powers; the ability to successfully aim various types of watercraft, rather than be "blown about," promised much. This reemergence, though, was not to last. In the same way wind power preplaced oared, other technologies and tactics would evolve and replace the ram. The second life cycle of the ram would come to an end and its use to achieve combat effects would not be revisited.

The earliest ram appeared on naval vessels sometime after 1000 B.C.¹ Its inception brought about great changes in naval warfare. Up until this time, watercraft were primarily designed as troop transports.² Though some battles did take place at sea, naval power was more a function of moving men and resources to strategic locations on land than

¹ James L. George, *History of Warships: From Ancient Times to the Twenty-First Century* (Annapolis, MD: Naval Institute Press, 1998), 13.

² Lionel Casson, *Ships and Seamanship in the Ancient World* (Princeton, NJ: Princeton University Press, 1971), 49.

engaging in hand-to-hand combat from the decks of naval vessels. Watercraft design depended on troop capacity and how fast one could deliver troops to their intended location. Larger craft were able to achieve more effects at any given time by carrying more troops, while lighter vessels were able to project naval power faster.³ Naval powers had to balance size against weight to achieve their desired objectives.

With the introduction of the ram, the naval vessel changed from being merely a vehicle for transporting troops to an instrument for combat.⁴ The naval ram could, in theory, make every watercraft a weapon. The appeal of the ram as a weapon was largely based on harnessing the destructive power of a vessel. Although early seafaring people did not understand the dissipation of *kinetic energy* as the true measure of destructiveness, where mass is important but velocity is more important, they did grasp some of the notions of physics in their day-to-day lives.⁵ Larger, heavier vessels required more energy to stop or maneuver than their lighter counterparts. Regardless of size, the ability to exploit a vessel's potential power made the ram very appealing.

Watercraft design changed drastically once the concept of ramming took root. Two important features of the average war vessel had to change. First, designers had to strengthen the structure supporting the ram. Early rams were either made of dense wood, bronze, or iron.⁶ They were extremely heavy. Placement on the bow-end of a vessel affected both the balance and buoyancy of the craft. Addressing these challenges

³ James L. George, *History of Warships*, 14.

⁴ Robert L. O'Connell, *Of Arms and Men: A History of War, Weapons, and Aggression* (New York, NY: Oxford University Press, 1989), 54-55.

⁵ Energy is the true measure of destructiveness in a collision, since it must be dissipated by the two ships colliding. Energy is linearly proportional to mass but varies with square of velocity. A one ton vessel has half the kinetic energy of two ton vessel, if the vessels are moving at the same speeds. However, a one ton vessel traveling at two knots has a fourth of the kinetic energy of the same vessel moving at four knots.

⁶ Ann Natanson, "Raising the Ram," *History Today* 61, no. 8 (August 2011): 17-18.

alone required strengthening the bow and hull.⁷ Being able to withstand the impact associated with ramming other vessels compounded these requirements.⁸ In many cases, modifications to existing merchant vessels were not enough to address the new challenges. New vessels, considerably stouter in construction, were required.

Ship builders also had to address challenges associated with generating speed. Achieving the speed necessary to generate enough energy to produce destructive effects presented a significant challenge for early designers. Requirements for strengthening the structures of ram-equipped vessels had to be balanced with the capacity to generate velocity. Heavier ships required greater sources of power to move about. From the inception of the ram to mid-sixteenth century, oarsmen provided the primary source of power for combat vessels.⁹ To account for the greater weight associated with stronger structures, designers added more oarsmen. Adding more oarsmen meant bigger vessels. Larger craft capable of supporting the needs of more men translated to heavier vessels. Addressing the circular argument culminated in vessels comprised of multiple decks with numerous rowers on each deck.¹⁰ The naval power that could optimize the balance between weight and speed would be able to produce the most effective vessels for ramming. The costs associated with pursuing such a balance were substantial.

⁷ George, *History of Warships*, 14. Lionel Casson, *Ships and Seamanship in the Ancient World*, (Princeton, NJ: Princeton University Press, 1971), 49.

⁸ In a contest for control of the sea, the Syracusans engaged the Athenian fleet in Syracuse's Great Harbor. Prior to the engagement the Syracusans had substantially strengthened the prows of their vessels for head-on collisions. Their modifications allowed them to penetrate their adversary's vessels' weaker bows and ultimately led to the Athenian defeat. Robert B. Strassler, ed., *The Landmark Thucydides: A Comprehensive Guide to the Peloponnesian War* (New York, NY: Free Press, 1196), 448-451.

⁹ Though the sail also provided a source of power, sail technology did not yet support the speed requirements of modern navies. Many merchant ships had long operated under sail, and the earliest galleys had carried sails. However, despite the presence of the sail, galleys fought using oared power. Not until several refinements to sails, cannon, rudders, and general ship construction did the primacy of sail come about. George, *History of Warships*, 39.

¹⁰ Casson, *Ships and Seamanship in the Ancient World*, 53-54, 97-115.

Consequently, wealthier nations, with the resources necessary for research and development and a desire to rebuild their navies, were the dominant players in harnessing the power of the ram.

The appeal of the ram was also a product of the combat environment of the times. Naval vessels often came into direct contact with one another. Standoff technology with significant firepower did not come about until the latter part of the sixteen hundreds.¹¹ Up until this time, opposing military personnel hurled a variety of objects from the decks of their vessels. Objects ranged from rocks and arrows to clay pots filled with poisonous snakes and napalm-like substances.¹² Though the objects produced a wide range of destructive results, their effects were often not the decisive factor in combat. Naval vessels frequently had to close in proximity for their crews or complement of soldiers to engage in hand-to-hand combat.¹³ The quality of a vessel's troops and their boarding tactics were the key factors in determining the outcomes of naval engagements.¹⁴

The naval ram negated the uncertainties associated with hand-to-hand combat. With a single blow, a vessel could quickly end an

¹¹ Gunpowder came about the year 1000. The first guns appeared sometime during the early part of fourteenth century. William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago, IL: The University of Chicago Press, 1982), 39, 80. However, naval powers were unable to harness their destructive potential for some time. The first time artillery aboard naval vessels decided the outcome of a battle arguably occurred during the Battle of Lepanto in 1571. Naval artillery would achieve primacy during the engagements between the English and the Spanish Armadas in 1588. VADM William L. Rodgers, *Naval Warfare Under Oars: 4th to 16th Centuries, A Study of Strategy Tactics and Ship Design* (Annapolis, MD: United States Naval Institute, 1939), 215, 298.

¹² George, *History of Warships*, 21-25.

¹³ Casson, *Ships and Seamanship in the Ancient World*, 120-123.

¹⁴ Though naval artillery was decisive in the During the Battle of Lepanto, it was only pivotal with respect to one of the two major engagement locations. The tactic that dominated the other location involved traditional boarding tactics. The quality of the troops in close-quarters combat aboard the opposing side's vessels was the deciding factor, not the presence of presence of modern, advanced missiles, guns, grenades, bows, and other projectiles and weapons. Rodgers, *Naval Warfare Under Oars*, 196-210, 215.

engagement.¹⁵ Its promise, however, was based on more complex tactics than previously envisioned. Watercraft no longer maneuvered solely in relation to optimal boarding angles. Sea captains now had to factor in desired collision angles. Aside from being dependent on the vessel for mass and velocity, the effectiveness of the ram depended on the angle at which the attacking vessel struck its target.¹⁶ Achieving desired impact angles against a moving target required precise maneuvering. Coordinating the efforts of the oarsmen for directional control, while still producing the thrust necessary to produce the desired effect, was of utmost importance.¹⁷

The Age of Sail, beginning in the latter part of the 16th century, brought about significant changes to watercraft design, one of which was the ram's fall from grace.¹⁸ Naval powers placed less importance on the concept of the ram for several reasons. Perhaps the primary reason was the increased importance placed on capturing, versus destroying, naval vessels. The value of various watercraft had increased significantly with advancements in naval technology and firepower. Able to more effectively harness the power of wind via better sails and rigging, hull design, and steering mechanisms, naval vessels grew in size and

¹⁵ Not all naval powers built ram-equipped vessels or pursued collision-based tactics, however. Sinking the adversary's vessels was counterproductive when the objective was to acquire watercraft or their contents. Additionally, when one's forces were better suited to infantry-tactics than maneuver warfare, it was more advantageous to get close and let the deck-based marines decide the outcome of an engagement.

¹⁶ A variety of tactics were pursued to account for the difficulties associated with ramming. Tactics ranged from engagements involving prow-to-prow collisions to quickly moving through the adversary's formation, wheeling around, and attempting to strike a specific vessel in the broadside. Perhaps the most defensive of tactics involved the formation of a "wagon wheel" where a fleet of vessels circled their watercraft around a central point and kept their rams pointed outwards. When the opposing fleet closed, individual vessels were directed to attack based on desired pursuit angles. George, *History of Warships*, 19.

¹⁷ O'Connell, *Of Arms and Men*, 66.

¹⁸ The Age of Sail is the time period when sailing warships achieved primacy. The engagements between the English and Spanish Armadas in 1588 mark the first major battles of the age and consequently mark its beginning. Rodgers, *Naval Warfare Under Oars*, 241-335.

capacity.¹⁹ Consequently, they now carried greater amounts of cargo, housed increasing numbers of men, and wielded more long-range sources of firepower. Capturing large vessels could be quite profitable.²⁰ One could liquidate the vessel and its contents, ransom them, or add the craft to one's own fleet.

Another reason the ram was abandoned was due to changes in the character of firepower. Although cannon had entered the scene in the latter part of the fourteenth century, their effectiveness at sea remained questionable for some time. It was not until wrought iron gave way to bronze guns, muzzle-loaders replaced breach-loaders, and gun ports allowed for the placement of large guns below the main decks of vessels that the character of naval warfare changed.²¹ With the sinking of the first vessel by gunfire in 1513, sea captains had to reconsider the costs associated with engaging other vessels at close range.²²

In light of advancements in standoff firepower, pursuing ram-based tactics threatened both individual vessels and the fleet. To achieve higher angles for impact, attacking vessels ceded a considerable advantage.²³ An attacking vessel had to point at its intended target. Pointing narrowed the attacker's profile and, in turn, limited the number of guns the attacker could bring to bear on the target while completing its intercept. The targeted vessel, on the other hand, enjoyed the

¹⁹ As mentioned previously, galleys used sails for long range movements. However, for short range fighting, seamen pulled in the sails and used oars for maneuvering in combat.

²⁰ Ian Friel, "Oars, Sails and Guns: The English and War at Sea, c. 1200-c.1500," in *War at Sea in the Middle Ages and Renaissance*, ed. John B. Hattendorf and Richard W. Unger (Woodbridge, Suffolk, UK: The Boydell Press, 2003), 74.

²¹ George, *History of Warships*, 45.

²² Lionel Casson, *The Ancient Mariners: Seafarers and Sea Fighters of the Mediterranean in Ancient Times*, 2nd ed. (Princeton, NJ: Princeton University Press, 1991), 72-73. Friel, "The English War at Sea," 78-79.

²³ An attacker's intercept path also ceded another advantage to the targeted vessel. It helped the targeted vessel aim its guns. Vessels directly pointed at the target vessel did not require significant lead firing angles. Consequently, the targeted vessel's primary challenge involved determining the attackers range. This differed from the attacking vessel, which was challenged with solving for both range and lead firing angles.

advantage of its more numerous broadside guns. The targeted vessel reaped the benefits of this advantage for as long as it took the attacker to complete the intercept.

Pursuing ram-based tactics could endanger the entire fleet. Massing firepower had become much more difficult with more effective long-range gun employment and less controllable, wind-powered vessels. Fleet formations and the position of individual craft took on new importance.²⁴ For example, opposing lines of vessels depended heavily on the number of guns wielded from broadsides. One vessel changing course to ram an opposing vessel could, in a short amount of time, reduce the total number of broadside guns a fleet could bring to bear against the opposing line. Mismatches in firepower could develop in very little time. In battles where the survival of the fleet depended on the broadside contributions of every vessel, pursuing ram-based tactics could be disastrous.²⁵

Even without the threat of an opposing vessel's guns, ramming in the Age of Sail was more difficult than it had been in the past. Vessels were in constant motion. Regardless of whether the movement was desired, or the result of being pushed about by winds and currents, pursuing and striking faster, wind-powered targets without a highly controllable source of power were challenging endeavors. Whereas oarsmen had been an extremely effective controlling mechanism in the

²⁴ See chapters six, eight, for more information on mutual support, ship position, and fleet tactics. Mutual Sam Willis, *Fighting at Sea in the Eighteenth Century: The Art of Sailing Warfare* (Woodbridge, Suffolk, UK: The Boydell Press, 2008), 85-87, 113-128, 129-135.

²⁵ In 1811, during the Battle of Lissa, the French fleet was dealt an embarrassing blow by a smaller British force. Though the French vessels outnumbered British ships and would have been better off using their broadsides, French Captain Bernard Dubourdieu thought he could catch his enemy in more of a crossfire by cutting the British line into thirds. Consequently, he pointed two lines of French ships at the British vessels. As Dubourdieu's ships closed, the broadsides of the British vessels wreaked havoc on French bows. While the intent of the French was not to ram the British ships, the results would have been the same had their desire been to collide with their adversaries. David Lyon, *Sea Battles in Close-up: The Age of Nelson* (Annapolis, MD: Naval Institute Press, 1996), 143-149.

past, the age of sail did not offer such effective tools for starting, stopping, and steering naval vessels in any direction. If the other vessel had sails, it could simply turn away with the same motive force of the ship attempting to ram. The wind treated them equally and conferred no relative advantage.

The final reason naval powers discarded the ram likely had to do with design requirements. The rigging on the front of a ship presented impediments to the ram. With advancements in sailing technology, modern sailing vessels depended on lengthy pole-like extensions that stuck out well beyond the bow of the ship, for structural strength.²⁶ Numerous ropes, strung from masts to these extensions, provided tension along a vessel's longitudinal axis. If these protrusions were to become weakened or destroyed as the result of a collision, there was a greater chance for a damaged mast to fall in battle. Though the ram had undergone many modifications since its inception, none had to compete with such extensions.²⁷ Consequently, to avoid the many costs associated with designing rams of ridiculous lengths, ship builders abandoned the concept.

As the benefits of the ram no longer outweighed the costs associated with employing it, the first life cycle of the ram came to an end. However, the concept of the ram was not to disappear forever. Two technologies set the stage for the reemergence of the ram: steam engines and iron armor. Steam engines eliminated complex networks of rigging used on sailing ships, provided a more controllable source of power than wind, and once again allowed sea captains to harness the full might of

²⁶ One the longest rams, used by the Venetians and commonly known as the "spur," was about 18 feet long. Rodgers, *Naval Warfare Under Oars*, 232,

²⁷ The ram had numerous forms and functions, depending on the desires of naval powers. For example, some rams were short and blunted, to prevent being caught in the targeted vessel, while others had horizontal protrusions that would cause damage at shallower angles of impact. In terms of function, some rams were designed to cut the oars of opposing vessels, leaving the adversary unable to maneuver and incapable of denying a subsequent collision. Many rams doubled as boarding ladders when there was no desire to sink the enemy.

their vessels. Iron armour made it possible to survive the impacts of a barrage of projectiles while in route to a target.

The US Civil War effectively showcased the reemergence of the ram. Though the concept of ram-equipped vessels had been discussed for several decades prior to the first vessel's construction, it was the twin promises of steam and impenetrable armor that brought the concept to reality. With its reemergence in physical form, the ram became once again a close-to-kill technology. Determining the value of this technology demands a more comprehensive analysis of the ram's second lifecycle.

Equip and Sustain

The Confederate States Navy (CSN) first pursued the construction of vessels known as "ironclad rams."²⁸ Both in foreign lands and at home, the Confederacy sought powerful, yet affordable, solutions for breaking the Union's robust blockade. Abroad, the Confederacy attempted to procure larger and more powerful ram-equipped ships capable of challenging adversaries in deeper waters. At home, the South was able to produce a series of ram-equipped vessels that would galvanize a close-to-kill mentality.

The ram's appeal in the South is understandable for a variety of reasons. The Confederacy was severely out-resourced. The North had more people, a robust industrial base, and command of the sea. The ram, in theory, provided a cost-effective strategy for defeating an adversary with ample resources.²⁹ In comparison to erecting extremely costly fortifications or making any attempt to match the North soldier-for-soldier or ship-for-ship, the ram was an inexpensive option.³⁰ The superiority of the ram would in essence nullify the Union's numbers.

²⁸ Virgil C. Jones, *The Civil War at Sea: The Blockaders*, vol. 1, *January 1861 to March 1862*, (New York, NY: Holt, Rinehart, and Winston, 1960), 158.

²⁹ Jay W. Simson, *Naval Strategies of the Civil War: Confederate Innovations and Federal Opportunism* (Nashville, TN: Cumberland House, 2001), 37.

³⁰ Claude G. Rerube, "American Thunder Childs," *Naval History* 23, no. 3 (June 2010): 60-67.

Much of the zeal for the ram came from the simplicity of its design. Its potential was easy to envision and embrace. French ironclad vessels had recently showcased their survivability during the Crimean War; the iron armor negated the effects of modern firepower.³¹ Advancements in steam-power technology, to include the use of single and multiple turn screws, allowed modern vessels to achieve significant velocities and high degrees of maneuverability. The combination of invulnerability, higher speeds, and greater facility in turning made the ram both feasible and practical.³²

Designing the Confederate version of the ramming ship was not particularly difficult. One of the first and perhaps most famous, the Confederate States Ship (CSS) *Virginia*, was constructed from the remnants of a vessel that had been previously set afire and abandoned.³³ The *Virginia*'s finished form, and the whole of the Confederacy's ram fleet, consisted of a simple housing with angled sides. Gun ports were located in logical locations. Iron plating covered all of the surface areas that would be vulnerable to enemy fire. An iron ram was affixed to the bow.

³¹ In 1855, in a battle for Fort Kinburn, Ironclad French vessels were able to survive an onslaught of powerful Russian projectiles. In turn, French and British fires were able to destroy many Russian guns and bring about the fort's surrender. Rear Adm S.S. Robison and Mary L. Robison, *A History of Naval Tactics from 1530 to 1930: The Evolution of Tactical Maxims* (Annapolis, MD: The United States Naval Institute, 1942), 575-576. Helmut Pemsel, *A History of War at Sea: An Atlas and Chronology of Conflict at Sea from Earliest of Times to Present*, trans. Maj G. D. G. Smith (Annapolis, MD: Naval Institute Press, 1989), 90-91.

³² Though both the North and South had been slow to adopt the concept of the ram, the concept was not new. Colonel John Stevens had tested an elongated, "shot-proof" vessel in 1814-1815. His sons later modified the design of the steam-powered, screw-propelled ironclad to include an under-water ram. The new Steven's battery, however, was too far advanced to be conceptualized by decision makers of the time and was consequently abandoned by Congress in 1861, shortly before the War. Robison, *A History of Naval Tactics*, 560-562.

³³ Carl D. Park, *Ironclad Down: USS Merrimack-CSS Virginia from Construction to Destruction* (Annapolis, MD: Naval Institute Press, 2007), 134.

The pattern for construction was easy to follow and replicate. Consequently, substantial oversight was not required.³⁴

Though the concept of the ram provided a focused, easy to grasp, and simply translatable strategy, it did so with considerable costs. The ram turned out to be far more expensive than had been envisioned in both resources and time. The South's most obvious overestimations involved its overseas endeavors. Several Confederate agents had successfully infiltrated England and France and had secured contracts for new ram-equipped vessels.³⁵ However, due to the high costs associated with the ships' construction, ship building efforts would never come to fruition. The cost of a blue water-destined ram was estimated to be between two and two-and-a-half million dollars, and the South only had a quarter of the funds required.³⁶ Though the Confederacy found creative ways to pursue the foreign-built ram, the results never arrived in the time or in the form desired. Of the many circumstances contributing to the South's misfortunes in Europe, none were more consequential than the lack of funds.³⁷ Had the South better estimated the costs associated with producing a capital ship overseas, it could have cut its losses early and used those much needed resources elsewhere.

³⁴ Robert MacBride, *Civil War Ironclads: The Dawn of Naval Armor* (Philadelphia, PA: Chilton Books, 1962), 77.

³⁵ For detailed accounts on individuals, to include James D. Bulloch and Lieutenant James H. North, see Frank J. Merli, *Great Britain and the Confederate Navy: 1861-1865* (Bloomington, IN: Indiana University Press, 1970).

³⁶ Richard Lester, "Construction of Confederate Ironclad Rams in Great Britain," *Military Collector & Historian* 26, no. 2 (June 1974). Merli, *Great Britain and the Confederate Navy*, 136.

³⁷ Park comments on the South's financial woes through the lens of Tredegar Iron Works, who were responsible for much of the Confederacy's iron-related requirements; ranging from cannons and ammunition to iron plates for the ironclads. In highlighting how tight money was during the Civil War, Park notes, "Tredegar teetered on the edge of bankruptcy" as "the Confederated government was organized to the point where they were selling worthless bonds and printing imaginary money." Park, *Ironclad Down*, 106. Secretary of the Confederate Navy Stephen Russell Mallory commented on the status of the South's economy in the fall of 1862, "the country's domestic exchange was nearly exhausted." Consequently, he was "seriously apprehensive about the treasury's ability to meet the demands of the European contracts." Merli, *Great Britain and the Confederate Navy*, 146.

A less obvious, but no less significant, overestimation involved the resources necessary to ensure the ram's invulnerability. The success of the ram depended heavily on its armor. Though considerable testing had been done to determine the iron plate requirements for a single ironclad ram, little had been done to forecast the vast amounts of iron that were necessary for outfitting numerous vessels.³⁸ The Confederacy's capacity for producing iron plating was quite limited. Though the South abounded with ironworks, there was a shortage of rolling mills, which were necessary for making iron plates.³⁹ At the beginning of the war, the Confederacy only had two reliable mills.⁴⁰ Not until six months into the war did it contract for a third.⁴¹ The shortage in production capacity led to a significant iron deficit by the end of the war. By the fall of 1864, seven of the South's twenty-two vessels in production "were delayed for want of iron, a deficiency for the moment amounted to at least 4,230 tons."⁴²

The South also overestimated the resources it possessed to safeguard the ram's source of power. In addition to armor, the ram's success depended on its engines. Many of the confederacy's steam

³⁸ Testing had been not done to determine how thick the iron plates needed to be for the ironclads. The *Virginia's* requirements for two inch thick plate did not come about until after the decision had been made to build the ship. Merli, *Great Britain and the Confederate Navy*, 107-108.

³⁹ MacBride, *Civil War Ironclads*, 76.

⁴⁰ MacBride, *Civil War Ironclads*, 76.

⁴¹ MacBride, *Civil War Ironclads*, 76.

⁴² Virgil C. Jones, *The Civil War at Sea: The Final Effort*, vol. 3, *July 1863 to November 1865* (New York, NY: Holt, Rinehart, and Winston, 1962), 301. To make matters worse, the South had an inadequate rail system for moving iron-based resources around. Unfortunately for the South, other military-related requirements, like iron plating, took precedence over the production of new iron rails for railroads. The problems associated with this circular conundrum manifested themselves in a number of ways, one of which being delays in producing military vessels. Park, *Ironclad Down*, 130, 132. Merli, *Great Britain and the Confederate Navy*, 12. In some cases railroad tracks were sometimes torn up, melted down and used to supplement shortages. However, the practice of cannibalizing rail lines often had detrimental second and third-order effects when the transportation routes were needed later on.

plants were secondhand.⁴³ Confederate admiral Raphael Semmes commented on the status of the South's capacity to produce adequate modes of propulsion, "The South had neither shipyards nor workshops, steam mills or foundries, except in the most limited scale...We had not the means in the entire Confederacy of turning out a complete steam engine of any size."⁴⁴ The steam engines they did procure were often unreliable and did not guarantee the speed and maneuverability necessary to effectively close with a target.⁴⁵ The inability to outmaneuver and strike the enemy had detrimental results throughout the war.⁴⁶

Perhaps the most damaging cost associated with the ram did not come in the form of resources or time but rather in the loss of the initiative. Though the Confederacy primarily sought the ram for defensive purposes, it did cling to hope that the ram would provide a powerful asymmetric advantage for a strategic offensive. Had the Union not been able to counter the concept of the ram, the South's dream may have been realized.

The Confederate version of the ram scored its first victory at the mouth of the James River on March 8, 1862.⁴⁷ After exchanging several volleys of cannon fire, the CSS *Virginia* (formerly a Union vessel named *Merrimack*) smashed into the side of the United States Ship (USS)

⁴³ The engines of the vaunted CSS *Arkansas* were salvaged from a sunken river steamer. Such examples were common throughout the war. Simson, *Naval Strategies of the Civil War*, 114-115.

⁴⁴ Merli, *Great Britain and the Confederate Navy*, 13.

⁴⁵ The *Arkansas*' poor engines made it difficult to close with, or sufficiently maneuver towards, desired targets. Simson, *Naval Strategies of the Civil War*, 121.

⁴⁶ As both sides were able to produce iron plating throughout the war, the requirement for speed was especially important. In many cases vessels were not able to generate enough velocity to cause any damage. Sir William Laird Clowes "compiled and analyzed 74 cases in which rammings were attempted in naval warfare between 1861-1869." The results showed, "Thirty-six ended in no damage whatsoever, eighteen in slight damage, and only twenty in serious injury to rammer or ramee." Stanley L. Sandler, "The Day of the Ram," *Military Affairs* 40, no. 4 (December 1976): 177. W.L. Clowes, "The Ram in Action and in Accident," *RUSI XXXVII*, no. 193 (March 1894): 230.

⁴⁷ Jones, *The Civil War at Sea*, vol. I, 420-421.

Cumberland and sent it to the bottom of the shallow harbor. The *Merrimack* was able to easily penetrate the sides of *Cumberland* due to the Union vessel's wooden construct. The vast majority of the North's naval vessels at the time were made of wood and had little to no ironclad armor for protection. The successful engagement with the *Cumberland* was promising for Southern leadership. The Confederacy, equipped with just a very few rams, could make quick work of North's wooden fleet and perhaps break the blockade that constrained both imports and exports.

However, the initiative the Confederacy enjoyed would not last long. The USS *Monitor*, the Union's counter to South's ram, made its appearance at Hampton Roads and engaged the *Virginia* only a day after the *South* had earned its first ram victory. The *Monitor* was the Union's first attempt at producing an ironclad ram. Unlike the *Virginia*, the *Monitor*'s design was fairly complex. Though it was similar in that it had ironclad armor protecting its vulnerable surfaces, it was different in that it incorporated some of the most modern technologies of the time. Many of these technologies were effective counters for the *Virginia*'s strengths, and would serve as effective counters throughout the war.⁴⁸

Consequently, when the two engaged each other the day after the sensational sinking of the *Cumberland*, neither vessel commanded the day. The North was again at parity with the South.

Many factors explain why the Confederacy lost the initiative so quickly. Most noteworthy was the South's inability to conceal its close-to-kill strategy. The South had committed to building its overseas rams in May of 1861, and Secretary of the Confederate Navy ordered the

⁴⁸ The *Monitor* fired its guns from a gun turret that rotated while the vessel was in motion. This allowed the Union ship to fire at a target, regardless of where the vessel was pointed. Additionally, the *Monitor* was smaller than the Confederate vessels, had a lower profile relative to the water, and required less armor plating for protection. Combined with better engines, and a shallower draft than Southern counterparts, the *Monitor* was much more maneuverable and better suited for the shallow waters where much of coastal warfare took place.

construction of the *Virginia* in July.⁴⁹ The North signed the contract for its first ram in October of 1861, just two months later.⁵⁰ Though both sides had extensive knowledge of ironclad and steam technologies at the outbreak of the war, it was evidence of the South's efforts rather than a vision for powerful, shallow-water craft that allowed the Union to achieve parity.⁵¹

The Confederate version of the ram depended on the entirety of the vessel for success, not just an iron protrusion that extended from its bow. Producing massive naval vessels was not a simple endeavor. Materials, technologies, and men travelled great distances to come together in support of such grand projects.⁵² Protecting information regarding the numerous activities surrounding a ram's construction was quite difficult. Perhaps the most damaging information came from within, where Confederate newspapers accounted for many of the South's activities.⁵³ Union spies, located both in the South and abroad, easily kept Northern leadership abreast of the Confederacy's ram-related efforts.⁵⁴ The success of the Union's espionage efforts, as a result of the ram's significant information "footprint," enabled the North to effectively parry the South's coastal offensive.

Acquisitions beyond the Civil War

While much of the narrative above has focused on the Civil War, it is important to note all major naval powers were undergoing change as a result of the promises of steam power and iron armor. Foreign ship builders, as early as the 1840s, had produced vessels whose hulls were

⁴⁹ Simson, *Naval Strategies of the Civil War*, 16-17. Park, *Ironclad Down*, 135.

⁵⁰ MacBride, *Civil War Ironclads*, 13.

⁵¹ Simson, *Naval Strategies of the Civil War*, 60-64.

⁵² Many of the South's workers and specialties came from the North's industrial base. The migration of intellectual capital, resulting from hiring workers across vast territories made it difficult to maintain secrecy. Compounding the problem was the migration of intellectual capital resulting from people choosing sides at the outbreak of the war. Park, *Ironclad Down*, 104-106.

⁵³ Simson, *Naval Strategies of the Civil War*, 48-49.

⁵⁴ Park, *Ironclad Down*, 107. Jones, *The Civil War at Sea*, vol. 1, 159, 233, 253-254.

entirely made of iron.⁵⁵ Powered by steam, many warships leading up to the Civil War and thereafter sported rams. The rams' successes in the Civil War and the Battle of Lissa in 1866 led to all navies possessing ram-equipped vessels.

The post-Civil War costs of these rams were substantial. However, as ship-building, metallurgy, and weapons technologies advanced, the cost for a ram dropped relative to other vessels of the time. Ironclad vessels, depending on the latest advancements in gun, torpedo, and iron armor technologies, were extremely expensive. Ram-based vessels, mainly dependent on strengthened bows and engines for generating speed, were relatively inexpensive. The USS *Katahdin*, the last of rams to be built by the United States, cost \$930,000 in 1890.⁵⁶ This was approximately a quarter of the cost of an armor-plated, gun-bearing ship of the time.⁵⁷

Peacetime Employment

The concept of the ram in its modern form provided no remarkable benefits during times of peace. The ram did, however, present two costs. For one, it was extremely difficult to train with the ram. The effects of collisions depended on a variety of factors, to include both the attacker's and the target's velocities and turn performances, the mass of the attacker's vessel, the material composition of targeted craft, and the shape of the attacker's ram.⁵⁸ Naval strategists and tacticians spent the majority of the 19th century trying to decode the secrets surrounding

⁵⁵ Robison, *A History of Naval Tactics*, 549, 570, 588-589.

⁵⁶ Lt Col Robert H. Rankin, "USS *Katahdin* – Last of the Rams," *United States Naval Institute Proceedings* 84, no. 10, (October 1958): 146.

⁵⁷ Rerube, "American Thunder Childs," 66.

⁵⁸ The shape and size of the ram, along with the angle of impact, were important factors in determining destructive effects. Vertical, protruding, rounded, and pointed rams favored impact angles perpendicular to the beam of the targeted vessel. Horizontal rams or rams equipped with horizontal plates favored shallower, slashing or glancing, angles of impact. "The Ward Ram for War-ships," *Science* 13, no. 334 (May 1901): 496-497.

maneuver warfare.⁵⁹ Theoretically accounting for these factors was quite difficult.

Compounding conceptual issues were illogical conclusions derived from “live” training. Though most navies could not go out and smash massive vessels together on a regular basis, some naval powers did have sufficient resources to practice ramming. In 1868, Russian admiral Gregoire Boutakov conducted 21 experiments involving collisions between 200-ton gunboats.⁶⁰ Pairs of vessels would square off and maneuver until a collision took place. The captain of a rammed vessel would be replaced while the victor would remain in command for another duel. The results revealed “the shortest elapsed time to ram was five minutes; the longest, fifty minutes; the average, twenty minutes.”⁶¹

Advocates of the ram viewed the engagements as a success.⁶² However, many of their assessments negated the realities of combat. While all of Admiral Boutakov’s duels resulted in a collision, none of the tests involved a realistic combat environment. Though other vessels were available, only two vessels were part of the test at any given time. There was no allowance made for teaming up on an individual vessel.

⁵⁹ For a chronology of doctrinal publications related to the evolution of maneuvers, see chapters XLII “Post Civil War Tactical Developments.” Some noteworthy shortfalls included ignoring: “the relative motion of opponents, factors of wind and sea, influence of wakes, and rates and acceleration and deceleration of ships of different displacements.” Robison, *A History of Naval Tactics*, 664-690. See also sections II, II, and IV of Matthew Allen, “The Deployment of Untried Technology: British Naval Tactics in the Ironclad Era,” *War in History* 15, no. 3 (July 2008): 277-291

⁶⁰ The gunboats did not possess a ram and were padded with fenders to prevent being damaged during a collision. Robison, *A History of Naval Tactics*, 681-682.

⁶¹ Robison, *A History of Naval Tactics*, 681-682.

⁶² Robison, *A History of Naval Tactics*, 681-682. The British believed, as the Russians did, the ram was complementary, and in many cases, subordinate to the gun. This was largely based on expectations for an engagement to last a minimum of ten minutes. John Knox Laughton, “Essay on Naval Tactics,” *The Gun, Ram, and Torpedo: The Influence of Modern Ships and Guns, Rams, Torpedoes and other Weapons, on a Naval Action in the Open Sea* (Pall Mall, London, UK: J. Griffin and Co., 1874), 93. The “live-fire” tests between HMS *Glatton* and *Hotspur* further supported opinions in favor of the ram. While both vessels maneuvered, gunners aboard the *Hotspur* fired repeatedly at the *Glatton*. The results were dismal, even despite firing at “point-blank range on a clear, calm day.” Sandler, “The Day of the Ram,” 177. Nathaniel Barnaby, “Lessons from the “Hotspur-Glatton” Experiment,” *RUSI* 17, no. 3 (June 1873): 293-309.

Additionally, Admiral Boutakov failed to account for the “fog and friction” effects of the countless projectiles that would likely be fired and absorbed during an intercept.

The more tangible training costs involved unintentional collisions between ram-equipped vessels and other watercraft. On numerous occasions, seafaring captains have accidentally rammed other vessels during peacetime maneuvers.⁶³ Many of the incidents resulted in loss of a ship or a number of human lives. Perhaps the most sensational collision took place in 1893, where the ram-equipped Her Majesty’s Ship (HMS) *Camperdown* struck and penetrated the British flagship *Victoria* while practicing close-quarters training maneuvers.⁶⁴ The collision resulted in the loss of the *Victoria* and death of 358 crew members. Although the collision was accidental, it highlighted the obvious dangers associated with ram-based training.

While the ram was problematic for training, it was even more of an issue during peacetime movements not involving tactical maneuvers. For example, between 1945 and 1984, there were about 115 collisions involving British warships.⁶⁵ A number of ships were severely damaged or sunk and countless lives were lost as the result of accidental collisions involving ram-equipped ships. Regardless of whether the causes were night-time conditions, inclement weather, or a simple lack of situational awareness, the fact that the ram could pose weighty unintended consequences during times of peace is noteworthy.

Wartime Employment

The ram did, however, provide some important wartime benefits. Perhaps the most significant benefits during the Civil War came from the

⁶³ Sandler, “The Day of the Ram,” 177.

⁶⁴ Allen, “The Deployment of Untried Technology,” 270. Stanley L. Sandler, “The Day of the Ram,” 175.

⁶⁵ David K. Brown and Phillip Pugh, “Ramming,” in *Warship 1990*, ed. Robert Gardiner (Annapolis, MD: Naval Institute Press, 1990), 21. Clowes, “The Ram in Action and in Accident,” 232-233.

psychological impacts it had on its captains and crews. The ram provided a clear vision for all military operators. The captains were emboldened by its promised power and did not hesitate to use it for its intended purpose. When the *Virginia* engaged its first victim, the *Cumberland*, its captain did not hesitate to use the ram.⁶⁶ Ram captains, on both sides, fought with equal vigor during the war and readily rammed any opposing vessels they encountered. Crewmen were likewise mentally prepared for close combat. There was no question of whether or not one was to engage the enemy in the most dangerous of naval environments.⁶⁷ The ram promised contact and in turn made the expectations clear for its participants. Accordingly, crewmembers readied both themselves and their stations for the variety of mental and physical challenges that were expected to be encountered.

The ram also provided a sense of security for military members. Even when severely crippled by enemy fire or short on critical resources, like coal, ammunition, and gun powder, members of ironclad rams still believed they possessed a very powerful weapon. Because of the ram's enduring nature, many of its operators thought there was a chance for victory. Confederate rams often fought well outnumbered, not as the result of their captains' chivalrous conquests, but rather as the result of the weapon they possessed.⁶⁸ They understood while it was possible to render a ram's guns ineffective, it was extremely difficult to destroy the

⁶⁶ Jones, *The Civil War at Sea*, vol. 1, 416-417.

⁶⁷ Crewman regularly covered the decks of their vessels with sand when preparing for the engagement with an enemy. The sand served as a source of traction as many of the vessel's surfaces were expected to be covered with blood. Traction was important for fighting off boarders from adversary vessels. Virgil C. Jones, *The Civil War at Sea: The River War*, vol. 2, *March 1862 to July 1863* (New York, NY: Holt, Rinehart, and Winston, 1961), 194.

⁶⁸ On July 12, 1862 the *Arkansas* engaged more than thirty Union vessels. During the engagement, the Confederate vessel attempted to ram the adversary on multiple occasions. Simson, *Naval Strategies of the Civil War*, 114-118. On August 5, 1864 the *CSS Tennessee*, in a similar situation took on seventeen Federal ships. Jones, *The Civil War at Sea*, vol. 2, 251-260.

ram in its entirety. The ram effectively secured the hopes of those who plied the seas in it.

Furthermore, the ram allowed for a surprise attack. While the *Virginia* had scored the first victory of the war, it was not the first time a Confederate ram had been used. The CSS *Manassas* had snuck up on and rammed the USS *Richmond* near New Orleans five months before the battle at Hampton Roads. The attack took place at night, while the Union vessel was anchored. The *Manassas*, formerly a tug, had been cut down, covered with iron plating, and outfitted with a 20 foot ram.⁶⁹ She had an extremely low profile and resembled a “huge cigar floating in the water or a submarine minus the conning tower.”⁷⁰ Her low profile provided a unique opportunity for a surprise attack.⁷¹

In contrast to the ram’s benefits, however, there were significant costs associated with using it in war. One of the most unfavorable costs involved the time required to engage an adversary or multiple adversaries. Ramming effectiveness depended on steering a vessel to close proximity and subsequently striking the targeted vessel with enough force to render it “dead in the water.” Maneuver warfare on the water was often highly dynamic. If one missed striking his target, due to poor aim or target maneuvers, it would often take a long time to turn around to reengage the same target.⁷² Even when rams were fixed to both ends of ironclad vessels, creating “double enders,” captains who missed their targets would still have to stop, reverse gears, and attempt to impact their target with enough speed to cause damage. Ramming required aiming an entire vessel rather than a gun. It was difficult, often time consuming, and many times prevented one ram from quickly engaging multiple adversaries.

⁶⁹ Simson, *Naval Strategies of the Civil War*, 94-95.

⁷⁰ Simson, *Naval Strategies of the Civil War*, 94-95.

⁷¹ Simson, *Naval Strategies of the Civil War*, 94-95.

⁷² Simspn, *Naval Strategies of the Civil War*, 85, 118.

Compounding the time required to engage multiple targets was the likelihood of causing damage to one's own vessel during an engagement. Damage could occur in multiple ways. The most obvious way involves the ram breaking during impact. In its engagement with the *Cumberland*, the *Virginia*'s ram got stuck in the side of the Union vessel and a portion of the ram was subsequently ripped off.⁷³ The loss of the ram had detrimental second-order effects. On one hand, men aboard the *Virginia* had to repair major leaks in the bow of their vessel.⁷⁴ Perhaps more importantly, the *Virginia*, no longer possessing an effective means to spear her adversary, was unable to pierce the sides of the *Monitor* the next day.⁷⁵

Another way damage may occur is by the attacking vessel getting caught in its target. On several occasions, rams were caught in their targets and effectively sunk along with their battered prey. If the attacker did not have the engine capacity to reverse its course and pull itself free from the target, the deadly result would be the same for both vessels. The *CSS Albemarle* barely escaped disaster after being caught in the side of the *USS Southfield*. Had the Union vessel not rolled over and released the *Albermarle* from her side, the *Southfield* would likely have taken the Confederate ram down with her.⁷⁶

Sometimes, being caught up for an extended period of time was just as damaging as being sunk. Immobilized in the presence of multiple adversaries often invited being rammed or "shot to hell" at point blank ranges. In the above example, the *Southfield*'s sister vessel *Miami* blasted the sides of the immobile *Albermarle* while the Confederate crewmen worked to free the vessel. Fortunately for the *Albermarle*, "the *Miami*'s guns were still loaded with shells for use against Confederate

⁷³ Simson, *Naval Strategies of the Civil War*, 82.

⁷⁴ Simson, *Naval Strategies of the Civil War*, 82, 85.

⁷⁵ Simson, *Naval Strategies of the Civil War*, 85.

⁷⁶ Robert G. Elliot, *Ironclad of the Roanoke: Gilber Elliot's Albermarle* (Shippensburg, PA: White Mane Publishing Co., Inc., 1994), 179. MacBride, *Civil War Ironclads*, 101.

infantry.”⁷⁷ The shells did not penetrate the vessel’s armor and the Confederacy was able to avoid a major loss.

An inability to reach desired targets also plagued the South during the war. Many rams were unable to engage their adversaries due to their relatively deep drafts. In light of gun technology, getting close to one’s adversary required substantial protection. Protection meant heavy armor and heavy armor meant more weight. Heavier vessels, in general, equated to deeper drafts. The side whose vessels had lighter drafts held the proverbial “high ground,” and could negotiate waters that the enemy could not. During the epic battle on the James River, the *Monitor* was able to maneuver in shoal waters where the *Virginia* could not go.⁷⁸ Though lighter rams would likely not have altered the course of the war, they would have made the Confederates’ instruments for war far more deadly.

Combat after the Civil War

In the year following the US Civil War, the ram was again employed with devastating effects. In 1866, during Battle of Lissa, a portion of the Austrian Navy engaged Italian vessels in the Eastern Mediterranean.⁷⁹ During the battle, both sides attempted to ram one another on multiple occasions. However, despite close-quarters combat lasting an hour and twenty minutes, only two ships were sunk; and only one by ramming.⁸⁰

The results of the Battle of Lissa were comparable to those of Hampton Roads in March of 1862. In total, the Italians lost a total of 620 men and two ships.⁸¹ The Austrians, on the other hand, lost a total

⁷⁷ MacBride, *Civil War Ironclads*, 101.

⁷⁸ MacBride, *Civil War Ironclads*, 86-88, 101. Capt John R. Eggleston, “Captain Eggleston’s Narrative of the Battle of the Merrimac,” in *Blue & Gray at Sea: Naval Memoirs of the Civil War*, ed. Brian M. Thomson (New York, NY: Forge, 2003) 403. Jay Simson, *Naval Strategies of the Civil War*, 83, 86.

⁷⁹ Robison, *A History of Naval Tactics*, 661.

⁸⁰ The *Ré d’Italia* sunk shortly after being rammed by Austrian Admiral Tegethoff in the *Ferdinand Max*.

⁸¹ Robison, *A History of Naval Tactics*, 663.

of 41 men.⁸² Though many of the losses were due to cannon fires, the most devastating effects came from the ram. The ram, in a short period of time, had brought down an entire ship and her crew.

Based on the battle's sensational results, naval powers were moved to further pursue the ram and ram-based tactics.⁸³ However, their analyses were based more on the results than judicial analysis of what had made the ram effective. Naval powers overlooked two factors that had uniquely contributed to the sinking of the *Ré d'Italia*. First, Admiral Tegethoff elected to ram the *Ré d'Italia* after the Italian vessel had been disabled by a previous collision and was dead in the water.⁸⁴ Second, of the ten Italian heavy ironclads present, only the *Ré d'Italia* and one other Italian ship had wooden hulls.⁸⁵ The rest of the ironclads all had iron hulls and had withstood the effects of multiple collisions during the battle.

The ram would not be used again in battle until the summer of 1879. During the Chilean-Peruvian War, the Peruvian ironclad ram *Huascar* engaged Chilean vessels on a number of occasions. Perhaps the most noteworthy engagement involved the struggle between the *Huascar* and the Chilean cruiser, *Esmeralda*. "To avoid endangering people on shore," the captain of the *Huascar* decided to sink the *Esmeralda* solely by the use of the ram. The ensuing battle took four hours and on the third and last collision the *Huascar* sank the Chilean adversary.⁸⁶

End of an Era?

By World War I, most naval powers no longer incorporated the ram into the designs of their warships. The ram's second fall from prominence would come as naval powers finally embraced the effects of

⁸² Robison, *A History of Naval Tactics*, 663.

⁸³ Helmut Pemsel, *A History of War at Sea*, 93.

⁸⁴ Robison, *A History of Naval Tactics*, 663.

⁸⁵ Robison, *A History of Naval Tactics*, 661.

⁸⁶ Robison, *A History of Naval Tactics*, 710-711.

modern firepower both on top of and below the water.⁸⁷ Engagements could be decided in minutes rather than hours and did not allow for time consuming maneuvers to close with the enemy. Though ram-based tactics were still being discussed, it was the presence of more advanced guns and submerged torpedoes, rather than the ram, which determined the outcomes of the Chinese-Japanese, Spanish-American, and Russo-Japanese Wars.⁸⁸ Perhaps the tactics of the Japanese best summed up naval employment during these wars: “follow the leader, fire at effective range, maintain that range, and employ torpedo boats only against disabled ships or at night; there was no planned melee; no charge through; no ramming.”⁸⁹

However, the concept of the ram did not disappear *completely*. Although, the ram disappeared from warship design, the concept of the ram would reemerge in naval activities that were not based on combat. Beginning in the first half of the 20th century, commerce-based ship-builders incorporated bulbous bows into their designs.⁹⁰ The new bows negated much of the friction and wave-making effects that made it more

⁸⁷ Additionally, naval powers likely believed iron hulls of modern vessels would achieve the ram's effects without having to incorporate expensive, reinforced prows into ship design. Some leaders and experts contended the *Victoria* sunk as a result of the impact from the *Camperdown's* hardened upper parts rather than the ship's ram. Clowes, “The Ram in Action and in Accident,” 237.

⁸⁸ The arguments surrounding the gun, ram, and torpedo were extensive. For much of the second half of the 20th century, many naval powers put the ram on equal footing as the other standoff technologies. It was not until combat results showed guns and torpedoes were able to destroy the opposition prior to coming into close quarters did the ram fall from primacy. See previous notes on chronology of published naval doctrine. See also Michael Epkenhans, “Technology, Shipbuilding and Future Combat in Germany, 1880-1914,” in *Technology and Naval Combat in the Twentieth Century and Beyond*, ed. Phillips Payson O'Brien (Portland, OR: Frank Cass Publishers, 2001), 53-67. For accounts of naval employment during the three wars, see Robison, *A History of Naval Tactics*, 737-744, 753-773, 780-794. Helmut Pemsel, *A History of War at Sea*, 94-101.

⁸⁹ Robison, *A History of Naval Tactics*, 793.

⁹⁰ Larrie D. Ferreiro, “The Social History of the Bulbous Bow,” *Technology and Culture* 52, (April 2011), 348-357.

difficult to move through the water.⁹¹ Vessels equipped with the new bulbous fronts were able to travel faster than their non-equipped counterparts. Their presence is seen on ships today.

Nor did the practice of ramming go away. Through the 20th century, there were numerous instances in which sea captains rammed or attempted to ram other vessels. During World War I, both ships and submarines were the targets for ramming.⁹² In the Battle of Jutland, the cruiser HMS *Cleopatra* rammed and sank German destroyer G194.⁹³ Later in World War II, ships and submarines again rammed and several more vessels were sunk as the result of intentional collisions.⁹⁴ 19 of the 178 submarines sunk during the war were the result of deliberate attempts to ram.⁹⁵ In some instances, combat vessels were the target. While attempting to disrupt the Japanese economy, the US submarine *Parch* came under the close-quarters attacks of a group of Japanese commerce vessels.⁹⁶ Perhaps one of the most famous rammings involved the collision between a Japanese destroyer and future US President John F. Kennedy's Patrol Torpedo boat in the Blackett Strait of the Solomon

⁹¹ Though the bows were not intended for ramming, they looked very much like the underwater rams of the past. As had been the case with rams in the latter part of the 19th century, they also produced extremely damaging unintentional consequences. Accidental collisions between commercial liners and bulbous-bow equipped vessels have resulted in lost ships and hundreds of casualties. As sea-going commerce is much more prevalent than the presence of combat ships, the presence of "ship killers" on more ships is noteworthy, especially in light of the amount of traffic on the seas today. Larrie D. Ferreiro, "The Social History of the Bulbous Bow," 358-359.

⁹² For some examples of submarine losses see Naval History Division, Office of the Chief of Naval Operations, *United States Submarine Losses: World War II, reissued with an appendix of Axis submarine losses*, 5th ed. (Washington, D.C.: U.S. Government Printing Office, 1963).

⁹³ Jonathan Sutherland and Diane Canwell, *The Battle of Jutland* (Bloomington, IN: Pen & Sword Maritime, 2007), 56. For other examples of ramming attempts and resulting losses, see David Hepper, *British Warship Losses in the Ironclad Era: 1860-1919* (St Paul, MN: MBI Publishing Co).

⁹⁴ See Karl E. Heden, *Sunken Ships World War II: US Naval Chronology, Including Submarine Losses of the United States, England, Germany, Japan, Italy*.

⁹⁵ Brown, "Ramming," 28, 33.

⁹⁶ Stephen L. Moore, *Battle Surface!*; Lawson P. "Red" Ramage and the War Patrols of the USS *Parch* (Annapolis, MD: Naval Institute Press, 2011), 110-117.

Islands.⁹⁷ Though these are just a few examples, they highlight an enduring behavior in close-quarters engagements.

Conclusions

Based on the above analysis, there is still little value for a ram on today's combat vessels. Perhaps the most influential reasons for this assessment have to do with the perceived likelihood of closing with the enemy. Weighing into the calculations of today's ship captains are war vessels equipped with a large variety and number of reliable and effective standoff weapons. The munitions projected from these weapons are fast, highly maneuverable, and in many cases guided by sophisticated tracking technologies.⁹⁸ As ships are much slower and less maneuverable than the guided weapons, closing on the modern war vessel will undoubtedly require absorbing many standoff effects, most of which are detrimental to survival.⁹⁹ Further complicating the ability to close is the capacity to detect an adversary at range. While weather, darkness, terrain, and the depths of the sea offered opportunities for achieving surprise in the past, the same is not the case today. Ship and submarine-based radars and sonars, in addition to aircraft and satellite technologies, drastically reduce the adversary's options for a "sneak-attack."

However, it is interesting that leaders in the recent past pursued the ram for as long as they did when the likelihood of closing with the enemy was just as improbable as it is today. Like moths to a flame,

⁹⁷ See John F. Kennedy Presidential Library and Museum Web site, "John F. Kennedy and PT109," <http://www.jfklibrary.org/JFK/JFK-in-History/John-F-Kennedy-and-PT109.aspx>.

⁹⁸ This comment does not include the effects delivered by aircraft. Ship-based effects range from guided, supersonic missiles and homing torpedoes to computer-aimed guns and radar-aided cannons.

⁹⁹ The obvious counter to this line of reasoning is a surprise attack by a vessel operating in close quarters, where there is insufficient time to identify and target an attacking vessel. The surprise attack on the USS *Cole* in 2002 provides a contemporary example. Massimo Annati, "Maritime Security against Terrorism and Piracy," *Military Technology* 33, no. 3 (March 2009): 32-37.

naval powers during the Civil War and after chased the promise of the ram over developing other standoff technologies. Mysteriously, leaders clung to a mental perception of the ram's capacity to assure destruction. Many times their cognitive bias was so strong that they overlooked many of the factors that made ramming unlikely or long-range fires more effective. In the South's case, Confederate leaders hinged the majority of their naval strategy on the ram despite the presence of cheaper, yet comparable, alternative technologies and the Union's advantages in numbers and manufacturing capacity. In similar fashion, leaders of other nations followed suit for four decades following the war.

Furthermore, it is remarkable that the psychology of the ram extended beyond strategic aims. Long after the ram had disappeared from war vessels, naval commanders still rammed other vessels in the heat of battle. They often rammed, or attempted to ram, even though they had no training on the practice and were unsure as to what the effects of a collision would be on their own vessels. Whether their reasons for ramming were intentional or the result of reactionary instincts, their actions are noteworthy. Fortunately for them, the knife-like edges of their steel vessels often cut easily into their prey. While ramming may appear to have been foolhardy, it was generally effective.

Chapter 2

The Bayonet

Few men are killed by the bayonet; many are scared by it. Bayonets should be fixed when the fire fight starts. Bayonets must be sharpened by the individual soldier. The German hates the bayonet and is inferior to our men with it. Our men should know this.

General Georg S. Patton, Jr.

The history of the bayonet is brief when compared to the naval ram's persistence over three millennia. The military version of the bayonet came about during the 17th century and is still used by fielded forces today. However, while the bayonet's history is shorter, it is no less intriguing. The bayonet, like the ram, is a shock implement that extends the operator's reach and derives power from the body that wields it. However, rather than being an extension of a large, relatively heavy watercraft, moved about by the power of an engine, and steered by the helmsman; the bayonet depends on the reach, power, and skill of the individual soldier, sailor, and marine. As military practitioners realized the advantages of attaching metal, wood, and bone extensions to the ends of firearms, the bayonet evolved in form, shape, and size to accommodate a variety of functions and purposes. During its evolution, the bayonet, like the ram, competed with the promises of gunpowder and technological advancements in metallurgy and gun design. Although ground tactics for several centuries were designed around the bayonet charge, by World War I, developments in the range, rapidity, and lethality of small arms and artillery began to bring its utility into question. Since that time, US leaders have continued to debate the moral and material value of this relatively primitive close-to-kill instrument.

The first bayonet was a tool used for hunting. During the latter part of the 16th century and in the first half of the 17th century, hunters

used bayonets to “finish off” wounded animals.¹ After a hunter had fired a shot from one of the rudimentary firearms of the day, he would fix a metal extension into the muzzle of his gun, and subsequently stab an injured beast in a vital area, ultimately ending its life. Little to no force was required to thrust the metal extensions, in many cases edgeless and unsharpened, into the creature’s relatively soft body.

This early plug-style bayonet served many functions. Its primary purpose, other than killing, was to increase the distance between wielder and an intended target.² Should a wounded animal have the capacity to harm, either from a standing position or after having fallen, the hunter would have the ability to kill the animal while remaining a safe distance away. The bayonet also provided a timely backup to the hunter’s primary weapon. Guns used during this time were extremely cumbersome and time-consuming with regard to aiming, firing, and reloading.³ The need to engage an animal in a short amount of time, either for offensive or defensive purposes, was better satisfied by fixing a bayonet than attempting to fire the gun multiple times. The bayonet finally provided economy in terms of equipment. Hunters regularly carried some type of knife for cutting or impaling objects. By filing down or redesigning the hilts of these instruments, hunters were able to insert their modified knives into the muzzles of their firearms.⁴ The modified tools allowed them to achieve the effects of a knife and bayonet in the same instrument and eliminated the need to carry two pieces of equipment.⁵

¹ R. D. C. Evans and Frederick J Stephens, *The Bayonet: An Evolution and History* (Milton Keynes, Buckinghamshire, UK: Militaria Publications, 1985), 9-11.

² Evans, *The Bayonet*, 10-11.

³ Martina Sprague, *A History of Edged Weapon Warfare* (Yardley, PA: Westholme Publishing, LLC., 2009), 298.

⁴ Evans, *The Bayonet*, 9.

⁵ Evans, *The Bayonet*, 97.

Military strategists were quickly drawn to the advantages of the plug bayonet. Many armies during the 16th and 17th centuries were already exploiting the advantages of gunpowder in land warfare. Despite the utility of massed musketeers on the battlefield, however, the need for pikes and spears did not go away.⁶ Soldiers, sporting fourteen to sixteen-foot poles, protected rows of musketeers while they labored to aim, fire, and reload their primitive firearms.⁷ Opposing forces, wishing to engage the “soft” centers of individual formations, would have to negotiate these defensive barriers prior to reaching the more vulnerable personnel.⁸ The bayonet promised economy in warfare. It made every musketeer an effective pikeman.⁹ Muskets fitted with plug bayonets, though not as long as their piked predecessors, provided a reasonable barrier for rival cavalries and foot soldiers.

The plug bayonet, however, had several drawbacks. Perhaps the most important was its effect on the gun.¹⁰ Though inserting an object into the muzzle was at times desirable, blocking the barrel in general was problematic. If the gun had not been discharged, the bayonet prevented a soldier from quickly taking advantage of the longer-range capabilities of the firearm.¹¹ Additionally, when the need for the bayonet abated, removing and stowing the bayonet required time above and beyond that

⁶ Evans, *The Bayonet*, 11-12.

⁷ The arquebus and matchlock were the dominate firearms of the time. These weapons were large and heavy and often necessitated multiple infantrymen or a forked rest for employment. Their rates of fire were comparable to crossbows. Chandler, David, *The Art of Warfare on Land* (New York, NY: Hamlyn Publishing Group, 1974), 111.

⁸ Chandler, *The Art of Warfare on Land*, 110-112. David S. Stieghan (infantry branch historian, US Army Infantry School, Fort Benning, GA), interview by author, 22 March 2012.

⁹ Martin Van Creveld, *Command in War* (Cambridge, MA: Harvard University Press, 1985), 52. Michael Howard, *War in European History*, 2nd ed. (Oxford, NY: Oxford University Press, 2009), 60-61.

¹⁰ A. M. Low, *Musket to Machine-Gun* (New York, NY: Hutchinson & Co., Ltd., 1942), 59. Chandler, *The Art of Warfare on Land*, 130.

¹¹ Sprague, *A History of Edged Weapon Warfare*, 298.

required to reload, aim, and fire the gun. The time required was worse when the plug had an extremely tight fit.¹²

The plug bayonet also made it difficult to achieve other efficiencies on the battlefield. The effectiveness of the plug bayonet greatly depended on its fit into the muzzle of a firearm. Loosely fitted bayonets would simply fall out when a gun was lowered, fail to translate the full force of a thrust or slash, or be lost when removing them from human bodies.¹³ Many of these problems were due to manufacturing processes and the character of the battlefield. Replicating firearms prior to the Industrial Revolution did not involve precise manufacturing practices; the thicknesses and shapes of gun barrels and muzzles varied.¹⁴ To address these tolerances, bayonet manufacturers tailored each plug bayonet to its intended receiver; there was no guarantee one bayonet would achieve an adequate fit when paired with a different gun.¹⁵ The unique pairing resulted in challenges on the battlefield, where soldiers regularly replaced their guns and bayonets with those of enemy or their dead comrades.

As a result of these challenges, the plug bayonet's primacy on the battlefield did not last. Though the plug bayonet was the bayonet of choice during the 17th century, the concept of the bayonet evolved into something far more effective with the birth of the socket and sword-style bayonets. Both styles of bayonet addressed the problems associated with the plug bayonet. However, as with any new change, they came with a variety of new costs and benefits.

The socket bayonet dominated the battlefield during the 18th and the first half of the 19th centuries. As firearm technology did not

¹² Sprague, *A History of Edged Weapon Warfare*, 298.

¹³ Sprague, *A History of Edged Weapon Warfare*, 298.

¹⁴ Evans, *The Bayonet*, 16.

¹⁵ Evans, *The Bayonet*, 16. "Interchangeability" was a problem for all bayonet manufacturers until standardization became the norm. A. N. Hardin, Jr., *The American Bayonet: 1776-1964* (Meriden, CT: The Meriden Gravure Co., 1964), 15.

drastically change during this time period, military victories depended on echelons of men with bayonets moving forward to rout the enemy.¹⁶ The maximum effective range of a smooth-bore musket was about a hundred yards.¹⁷ This limited range, combined with the significant time required to reload the firearms, made it difficult to fire numerous volleys prior to closing with the enemy.¹⁸ Thus, opposing lines, supported by cavalry and artillery, fired volleys and advanced until one side broke ranks due to being pushed back by fixed bayonets.¹⁹ The side that was able to achieve the better rate of accurate fire, and was able to punch exploitable holes into adversary lines, enjoyed a significant advantage.

The design and evolution of the socket bayonet supported the gun's primary purpose. Like all bayonets, the socket bayonet was attached to the end of a gun. However, unlike the plug bayonet, the socket bayonet did not block the end of the barrel. It fit over the end of

¹⁶ The bayonet was part of a combined arms approach. "Success in battle depended in large measure on securing and retaining the initiative." Masses of bayonet-equipped soldiers smashing into vulnerable points in the enemy's formations often led to local victories or the routing of the enemy, where cavalry had a distinct advantage. Chandler, *The Art of Warfare on Land*, 161-162.

¹⁷ The maximum range of the musket was greater than a hundred yards. However, achieving longer- range effects depended on the size of the target, as the accuracy of gun became a factor. Stieghan, interview by author, 22 March 2012. Steven T. Ross, *From Flintlock to Rifle: Infantry Tactics, 1740-1866* (Portland, OR: Frank Cass, 1996), 25. Gregory Fremont-Barnes, "The British Army" in *Armies of the Napoleonic Wars* (Barnsley, South Yorkshire, UK: Pen & Sword Military, 2011), 133.

¹⁸ Early flintlocks could discharge three rounds in a minute. Howard, *War in European History*, 60-61. In the latter part of the 18th century, "A trained soldier could load fire his weapon [a French pattern 1777 musket] two or three times a minute under optimum conditions." Ross, *From Flintlock to Rifle*, 25. The British infantryman in the beginning of the 19th century "could fire one round in approximately 30 seconds." Fremont-Barnes, "The British Army," 133. These times are for smoothbore muskets.

¹⁹ Strategists and tacticians experimented with a variety of formations and compositions of fielded forces in attempts to balance firepower with maneuverability. During the French Revolution, military leaders employed infantry in line and column formations. The desired formation depended on the qualities of the infantrymen and command and control mechanisms in addition to the characters of the terrain and the adversary. Line formations maximized firepower and decreased the vulnerabilities associated with concentrated masses of men. However, they required a great deal of discipline in the face of enemy fires and were difficult to maneuver. Column formations were the easiest and fastest to maneuver but presented lucrative targets as men were grouped together and more vulnerable to concentrated fires from opposing cannons or muskets. See John A. Lynn, *The Bayonets of the Republic: Motivation and Tactics in the Army of Revolutionary France, 1791-94* (Boulder, CO: Westview Press, 1996), 243-259.

the muzzle and was locked into position by securing the collar-like base of the bayonet with a locking mechanism.²⁰ To ensure the bayonet did not block the shooter's field of view when aiming the gun, the extended portion of the bayonet protruded from the side or underneath the firearm.²¹

In addition to cleaning up the barrel, the thin iron extensions preserved the alignment of the firearm. The socket bayonet's long, edgeless, and many times multisided protrusions required the attacker to thrust the bayonet into his victim to achieve deadly effects.²² Whereas edged bayonets would support a slashing attack, such an attack with the common socket bayonet would more likely throw the victim off balance than cause a fatal wound.²³ Inadvertently, while thrusting the bayonet was a requirement for killing, it also preserved the alignment of the gun's barrel. Poorly manufactured gun barrels or barrels made from weaker materials would bend under the lateral forces produced by a slashing

²⁰ The locking mechanisms went through an evolution of their own. Various types of rings, springs, and other tightening mechanisms were developed to ensure the bayonet achieved the tightest fit possible while making it easy for the average soldier to quickly attach and detach the blade. Evans, *The Bayonet*, 17-48.

²¹ As soldiers used the bayonet more, the weapon evolved to extend out from the right side of the end of the gun prior to protruding forward. When the bayonet was fixed, this position gave the soldier unimpeded access to the muzzle-loader's ramrod. Additionally, the bayonet's position guaranteed that the more common right-handed shooter addressed the firearm in the manner that would allow him to transition back to a firing position in the fastest time possible. If the gun was placed on the ground, the outward bend would also keep the right side of the firearm, where the critical components for priming, cocking, and firing the gun were located, propped up above the ground's surface. Finally, the shape of the bayonet allowed soldiers to lock multiple guns together for storage. Three firearms with fixed bayonets could be interlocked together to form a triangular shaped teepee with the butts of the guns resting on the ground.²¹ This configuration kept the barrels of guns clean and made it easy to access the firearms in timely manner. See Martin J. Brayley, *Bayonets: An Illustrated History* (Iola, WI: KP Books, 2004). Evans, *The Bayonet*, 20. Stieghan, interview by author, 22 March 2012.

²² Multiple sides prevented bayonet wounds from closing on their own. Stieghan, interview by author, 22 March 2012.

²³ Sprague, *A History of Edged Weapon Warfare*, 305.

attack.²⁴ A bent barrel, as with excess weight, was far from desirable when attempting to achieve a high degree of firing accuracy.

Aside from how the socket bayonet improved the soldier's capacity to use the gun, it also ensured soldiers were able to defend themselves. Prior to the advent of rifling and the Minié ball, military forces typically engaged one another in open areas. Intricate systems of tunnels and trenches or dense vegetation were not significant factors in conducting warfare. Surviving an intimate engagement in these environments depended on one's reach and the ability to maneuver a weapon. When approached by enemy cavalry, being able to make contact with a horse or its rider prior to being trampled was paramount for survival. Once in close quarters with the adversary, the ability to outreach the enemy and maneuver the bayonet quickly in different directions was important.²⁵

As a tool, the socket bayonet was something of a mixed bag. Detached and stuck in the ground, the socket's collar-like base served as a useful holder for a candle.²⁶ Without the candle it provided a steady rest that eliminated the requirement for a shooting arm to support the end of a firearm.²⁷ In some instances, where the bayonet's design had drastically been modified, socket bayonets served as trowels. General John Pope, after reviewing field tests in 1871, commented on the utility of trowel bayonets, "I have seen the bayonets tested so that in fifteen (15) minutes two (2) companies of Infantry so covered themselves that they

²⁴ Evans, *The Bayonet*, 19.

²⁵ Based on these factors, a reasonable length for a firearm-bayonet combination was about six feet. The socket bayonet's design supported a variety of lengths that were sufficient to repel both opposing cavalries and the adversary's bayonets. Though thinner than its sword style counterparts, the thrusting motion required to employ the weapon permitted designers and manufacturers to lengthen the metal extension without sacrificing longitudinal structural integrity. The results of this capability were seen on the battlefield. Light infantry, carrying the longest guns, wielded bayonets averaging fourteen to sixteen inches in length. Artillerymen and officers, often sporting much shorter firearms based on their roles on the battlefield, brandished socket bayonets that were much longer. Evans, *The Bayonet*, 19. Stieghan, interview by author, 22 March 2012.

²⁶ Stieghan, interview by author, 22 March 2012.

²⁷ Evans, *The Bayonet*, 97. Stieghan, interview by author, 22 March 2012.

could not be seen at a distance of fifty (50) feet in front of an embankment which had been thrown up by them with the bayonet, and which could not be penetrated by a musket ball fired at a distance of ten (10) feet.”²⁸

The most noteworthy disadvantage of the typical socket bayonet was its poor utility as a hand-held weapon. The lack of a hefty hilt significantly reduced the bayonet’s handling characteristics when it was removed from the end of a gun. It was difficult to use the socket bayonet for anything other than a clumsy spike in close-quarters combat. The bayonet could not effectively be thrust into the body of an adversary without causing some degree of damage to the attacker’s hand.²⁹ Compounding the issue was the absence of an edge. Achieving effects with a slashing motion was even more difficult when the bayonet was removed from the end of the gun.

The sword bayonet, however, did address the more important dual-use shortfalls of the socket bayonet. As the name implies, the sword bayonet was an elongated edged weapon that was attached to the end of a soldier’s firearm. While some sword bayonets could also be categorized as socket bayonets, the vast majority showcased a hefty handle attached to multiple points along the side of a gun barrel. They, like socket bayonets, extended from the right side of the firearm until breach loaders became more common and a ramrod was no longer needed.³⁰ The blades

²⁸ Reports of Experiments with Rice’s Trowel Bayonet, National Armory, Springfield, MA, 1874. Although 10,000 of these bayonets would be ordered for further field tests, they would never be incorporated into the US military for general use. Many senior officers opposed the popular concept based on what they perceived as dangers to the soldiers’ firearms. The barrels of the guns would be exposed to much more dirt and stress as soldiers fixed the bayonets to their firearms to make more effective two-handed shovels. They were also concerned that wider blades, continually dulled by digging, would not be able to penetrate the body of an adversary. Finally, there were worries the trowels would not be menacing enough and the enemy would not run when faced with the weapon. Hardin, Jr., *The American Bayonet*, 196-205.

²⁹ Stieghan, interview by author, 22 March 2012.

³⁰ The placement of the bayonet on the bottom of the gun enhanced the weapon’s balance.

were extremely strong, sharpened on one or both sides, and, like the socket bayonet, sported a variety of lengths.³¹

Unlike its socket cousin, the sword bayonet was very effective as a hand-held weapon and tool. Whereas soldiers reliant upon the socket bayonet often carried additional edged weapons for close-quarters combat, those equipped with a sword bayonet did not need an additional instrument for personal defense.³² The sword bayonet also was an effective tool. The bayonet could be used to chop firewood and clear underbrush. If one side was serrated, the bayonet served as a rudimentary saw. Consequently, the sword bayonet's capacity as both a hand-held weapon and a tool, like the plug bayonet, afforded the soldier an opportunity to eliminate redundant pieces of equipment.

The sword bayonet was most advantageous, however, when it was attached to the firearm. While it extended the soldier's reach, it also provided two effective options for injuring the enemy. A soldier wielding a sword bayonet could either thrust the weapon into the enemy in the same manner as he would with a socket bayonet, or he could also attack in a slashing manner.³³ Slashing attacks offered several advantages. Unlike the dull-sided socket bayonet, a slash with a sword bayonet would likely impair the adversary's ability fight. If the slash was against a more vulnerable part of the body, to include the face and neck, the results could be deadly. Finally a slashing attack allowed the soldier to engage multiple adversaries at one time. By wheeling the weapon

³¹ Evans, *The Bayonet*, 49-96.

³² Stieghan, interview by author, 22 March 2012.

³³ Though slashing was a benefit it also incurred costs. As mentioned before, having a tight fit is important for a variety of reasons; the most important being the transfer of force. The sword bayonet was heavier than the common socket bayonet. Supporting the weight of the bayonet required robust mounting mechanisms. The mounts had to be strong longitudinally, where a thrust attack applied forces in the direction of the barrel. They also had to be strong laterally, where a slash attack applied forces perpendicular to the barrel. Not until the middle of the 19th century were adequate mounting mechanisms available. Consequently, sword bayonets prior to this time took second place to the more sturdy, socket style bayonets. Evans, *The Bayonet*, 66-71.

around, one could make contact with several targets in a short amount of time. This technique was much more efficient than having to pull a socket bayonet back out of the enemy prior to engaging another target.

Perhaps the most significant cost associated with the sword bayonet was the weapon's expense.³⁴ A substantial amount of time and resources were used to design and manufacture a sword bayonet. The bayonet required modifying and strengthening the hilts and crossbars of existing styles of swords. Additionally, firearm manufacturers had to make substantial changes to the ends of their guns to account for diverse methods of attachment. Though the bayonet was often shorter than the average sword, it still required significantly more metal than the typical socket-style bayonet. The presence of an edge meant the blade had to be sharpened. Finally, many times blades were redesigned based on perceived tradeoffs in shape versus strength. Overall, as compared to the requirements for a socket-style bayonet, these activities contributed to a relatively expensive product. Accordingly, expense made it impossible to provide a sword bayonet for every soldier. They were issued to men of rank and to personnel who needed a lengthy weapon for warding off a cavalry attack.³⁵

Much has been discussed about the costs and benefits associated with the types of bayonets that dominated the battlefield leading up to the 20th century. Though many of these bayonets were designed and first implemented outside of the United States, Americans were quick to embrace, and sometimes improve upon, foreign concepts. While the

³⁴ In the beginning it was cheaper for the US to procure European forms of the sword bayonet than to manufacture one. David S. Stieghan (infantry branch historian, US Army Infantry School, Fort Benning, GA), interview by author, 10 March 2012.

³⁵ Many soldiers did not use sword bayonets, however, even after having been issued one. Sword bayonets highlighted specialized personnel, such as sharp shooters, and identified positions of rank; opposing forces would target these important assets to achieve various advantages on the battlefield. Sword bayonets also placed additional burdens on the shooter. The width of the bayonet acted as a "barn door" for the wind and made accurately aiming the gun more difficult. Stieghan, interview by author, 22 March 2012.

bayonet had many costs, it was overall an important instrument for inflicting casualties and generating psychological effects, especially when it was difficult to achieve long-range effects on the battlefield.

Additionally, the bayonet many times provided an effective alternative for other hand-held weapons and tools. However, as firearm technology advanced during the middle part of the 19th century, the bayonet descended in importance. It was during this time, between the US Civil War and World War I, that the bayonet transitioned from primacy to a vestigial instrument.

With the advent of rifling and the Minié ball, battlefield tactics changed drastically, if not quickly. Rifling, a practice that had been around since the 15th century, involved etching spiraled grooves on the inside of a firearm's barrel. A shot traveling the length of the barrel would engage the grooves and spin as it left the muzzle. Spun shot had a smoother trajectory and consequently resulted in greater range and accuracy. However, because riflemen literally had to hammer a ball down the grooved barrel, rates of fire suffered; and the rifle remained the province of snipers and other specialists. It was ill suited to mass tactics until the invention of a French Captain Claude Minié in 1849. His new cylindro-conoidal ball, with a hollow base, descended easily down the rifled barrel and flanged outward when it took the explosive force of the powder to engage the rifling on the way out. The new projectile further increased the gun's range and accuracy while putting the rifle's reload rate on par with its smoothbore counterpart.³⁶

Despite an astonishing lag in adaptive tactics, large formations of men marching forward in ranks were rendered obsolete as rifled weapons became prevalent on the battlefield. The enemy's ability to fire numerous accurate volleys on a closing enemy made advancing on the open

³⁶ William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago, IL: The University of Chicago Press, 1982), 231.

battlefield an extremely costly affair.³⁷ Shelter behind earthen works, vegetation, and man-made structures was at a premium, and the bullet-stopping power of dirt encouraged soldiers to dig.³⁸ Minié had expanded the killing zone to nearly a thousand yards and rendered the bayonet charge over open ground a prohibitively expensive gambit.³⁹ Nonetheless, when officers thought they could overwhelm the adversary with superior numbers or induce psychological shock by rushing forward with fixed bayonets, they would order their men to advance over open terrain.⁴⁰ The horrific casualties of Shiloh, Antietam, and Gettysburg point to the folly.

Yet, despite the changes the rifle brought to battlefield, the bayonet still played a part in combat. The character of the guns and terrain during the US Civil War still provided time for the soldier to close with the enemy. With regard to firearms, the majority of soldiers wielded a rifled musket capable of firing a single round at a time. Guns designed to shoot several rounds in a minute were expensive and rare. As the concept of the breach-loading rifle was still in its infancy, the majority of rifles had to be loaded through the muzzle.⁴¹ Though soldiers had long perfected reloading in this manner, the practice still took time.

³⁷ Major General Ambrose E. Burnside lost more than 12,000 soldiers during a single day of senseless attacks at Fredericksburg, and one of its greatest heroes, Lieutenant General Ulysses S. Grant, sent nearly 14,000 men to slaughter in two days at Cold Harbor. General John Bell Hood, sacrificed the Army of Tennessee [7,000 troops] in a single heroic, yet mindless, frontal assault at the Battle of Franklin. Perry D. Jamieson, *Crossing the Deadly Ground: United States Army Tactics, 1865-1899* (Tuscaloosa, AL: The University of Alabama Press, 1994), 1-2.

³⁸ Ross, *From Flintlock to Rifle*, 182-183

³⁹ McNeill, *The Pursuit of Power*, 231. Ross, *From Flintlock to Rifle*, 170, 182.

⁴⁰ Brent Nosworthy, *The Blood Crucible of Courage: Fighting Methods and Combat Experience of the Civil War* (New York, NY: Carroll & Graf Publishers, 2003), 553-554.

⁴¹ Though the concept of the breech-loading needle gun had been passed around in the late 1840s, many actors, to include the Union and Confederacy, failed to universally adopt breech-loaded guns. It was not until the end of the Civil War that the North totally accepted the faster-loading rifle. Nosworthy, *The Blood Crucible of Courage*, 40-41, 609-628.

Consequently, in some circumstances, one could close while adversaries were reloading.

Additionally, some terrain during the American Civil War engendered close-quarters encounters. The eastern half of the United States comprised various types of vertical terrain, was heavily wooded, and contained many swamps and waterways supporting dense vegetation. The battlefield many times did not allow a senior officer to observe and direct the movements of his entire corps on an open battlefield. The typical fight took place in areas where the field of view was limited, both for those fighting in the battle and those making operations-level decisions. Closing in this environment was conceivable and in many instances necessitated. For example, many of the battles that took place in dense vegetation west of Fredericksburg entailed stumbling upon a surprised enemy and engaging in close-quarters combat.⁴²

While advancements in firearm technology and the character of the battlefield kept the spirit of bayonet alive during the US Civil War, the bayonet would become more vestigial in nature by World War I. Artillery rounds, having evolved from solid shot to explosive rounds far more powerful than their predecessors, produced murderous effects at long ranges.⁴³ Rifled machine guns, capable of firing hundreds of rounds a minute, could target an individual two thousand yards away.⁴⁴ The

⁴² See chapter 27, "Fighting in the Wilderness," Nosworthy, *The Blood Crucible of Courage*, 521-532.

⁴³ See chapter 7, "A Short Life: VII and VII Corps on 1 July," Robin Prior and Trevor Wilson, *The Somme* (New Haven, CT: Yale University Press, 2005), 71-81.

⁴⁴ The machine gun had achieved deadly effects decades prior to World War I. In the Russo-Turkish War of 1877-78, Russian Gatling guns [Gorloffs] broke up an entire Turkish offensive. During the Russo-Japanese War of 1904-5, Russians firing two machine guns used a thousand rounds in less than two minutes to wipe out two hundred Japanese at a range of three hundred yards. John. Ellis, *The Social History of the Machine Gun* (New York, NY: Pantheon Books, 1975), 65-68. The Americans also observed the Gatling gun's effectiveness in the battle for San Juan Hill, where "the Americans carried the San Juan works less than nine minutes after his [Lt John H. Parker's] Gatlings opened fire. Jamieson, *Crossing the Deadly Ground*, 139. However,

average soldier fired his rifle several times prior to reloading. At base, long-range firepower was exponentially more capable than that which had been present decades earlier.

As a result of the advancements in firepower, soldiers dug in. Thousands of miles of trenches were constructed during the war. The size and shape of the trenches varied greatly, depending on their purpose.⁴⁵ The land between the trenches, having been rent and tossed by artillery, was often a barren wasteland comprised of craters and the remains of vegetation and man-made structures. Negotiating this terrain was extremely difficult and time-consuming, even more so when the enemy laced the areas with barbed wire and other devices designed to slow down troop movements.⁴⁶

The amalgamation of better long-range firepower and unfavorable terrain made closing with the enemy almost impossible. During the first days of the war, the British and the French lost tens of thousands of soldiers in costly advances over difficult terrain in the presence of murderous fire. The Battle of the Somme produced 300,000 casualties in the first two weeks alone.⁴⁷ The odds of making it to a position where the bayonet could be used for effect were incredibly low.

Furthermore, when a soldier did close with the enemy, his ability to use a fixed bayonet was extremely limited. Engaging the enemy in close quarters often meant entering the adversary's system of trenches. In these confined spaces, wielding a foot-and-a-half blade attached to a

though the machine gun had produced significant results, it achieved primacy with the incredible numbers of deaths produced during the Great War. Every nation acknowledged the horrific results of Verdun and the Somme and could not disavow the primacy of the weapon.

⁴⁵ For example, trenches for communication were narrow while trenches designed for holding significant numbers of men were wider. See map, Arthur Guy Empey, *Over the Top* (New York, NY: The Knickerbocker Press, 1917).

⁴⁶ Prior, Robin and Trevor Wilson, *The Somme* (New Haven, CT: Yale University Press, 2005), 71-81.

⁴⁷ Tim Travers, *The Killing Ground: The British Army, the Western Front and the Emergence of Modern Warfare, 1900-1918* (Winchester, MA: Allen & Unwin Inc., 1987), xvii.

four-foot rifle was decidedly difficult.⁴⁸ The narrow character of most trenches limited a soldier's ability to maneuver longer weapons. One could not stick an adversary, remove the weapon, and easily redirect the weapon in a completely different direction. Slashing attacks were more difficult due to an inability to generate velocity with the end of the weapon. The trench environment was better suited for the use of shorter hand-held weapons: small shovels, various types of clubs, and knives.⁴⁹

A clear example of the change in attitude towards the bayonet was the widespread adoption of trench knives shortly before the war's end. Thousands of 1917 and 1918 US model trench knives would be issued to soldiers going to the front lines.⁵⁰ Despite the acquisition of the more favorable weapons, the spirit of the bayonet would not die with the war's end. US service members have been issued a variety of bayonets since World War I. The reasons for keeping the bayonet vary. Thus, further analysis is required to determine the value of this close-to-kill technology.

Equip and Sustain

The contemporary bayonet is an inexpensive piece of equipment that offers many more features than bayonets of the past. In 1986 the contract price for the US Army's M9 bayonet was \$49.86.⁵¹ The Marine Corps version, the OKC3S, cost \$38.53 in 2003.⁵² While these prices are significant when applied to orders of 315,600 bayonets for the Army and 104,487 for the Marine Corps, the cost ratios of bayonets to rifles remain in line with historical averages.⁵³ The M9 and OKC3S contract prices

⁴⁸ Stieghan, interview by author, 22 March 2012.

⁴⁹ Stieghan, interview by author, 22 March 2012.

⁵⁰ Stieghan, interview by author, 22 March 2012.

⁵¹ Comptroller General of the United States, *Decision: Matter of Imperial Schrade Corporation* (Washington, D.C.: General Accounting Office, 6 March 1987), 4.

⁵² Ms. Sue Green, 2003 OKC3S contract POC, Ontario Knife Company, to the author, email, 1 March 2012.

⁵³ Ms. Sue Green, 2003 OKC3S contract POC, Ontario Knife Company, to the author, email, 1 March 2012. Comptroller General of the United States, *Decision: Matter of*

were approximately a tenth of what their associated firearms cost. The average price for the contracted M16A2 rifle that was to be issued to light infantrymen in years ahead was \$420 in 1988.⁵⁴ In 2003, the more compact and technologically advanced version of the M16A2, the M4, cost \$986.⁵⁵ In relation to the \$1.45 socket bayonet that was fixed to the \$17 rifle or \$13.24 musket during the US Civil War, the bayonet's relative price has not changed significantly.⁵⁶

However, while the fractional price of the bayonet to the rifle is in line with historical norms, modern bayonets possess more capabilities than their counterparts of the past.⁵⁷ Bayonets with differing types of edges, like the M9 and the OKC3S, support a variety of purposes. While one side of the M9's blade may be used for cutting and slicing, a portion of the opposite side may be used for sawing or gripping wire. The OKC3S's design incorporates a serrated edge, for tearing through denser objects, on the same side as the smooth, sharpened blade. Though hollowed hilts capable of storing numerous small objects have not been a requirement for US military manufactures, their potential has not been ignored in niche, custom markets and foreign military designs. From matches to tweezers, bayonet handles are long and wide enough to store a variety of small objects. Finally, the scabbards of modern bayonets also add to their functionality. The M9's scabbard, when mated with

Imperial Schrade Corporation (Washington, D.C.: General Accounting Office, 6 March 1987), 4.

⁵⁴ This price was for a rifle and a single clip. It did not include ammunition, additional clips, or any additional attachments for the rifle. Comptroller General of the United States, *Decision: Matter of Colt Industries, Inc.* (Washington, D.C.: General Accounting Office, 23 January 1989), 2.

⁵⁵ The contract was for 124,803 guns at total cost of \$123,035,995. Office of the Assistant Secretary of Defense, *Contract*, Public Affairs Release 389-04 (Washington, D.C.: Department of Defense, 30 April, 2004), <http://www.defense.gov/contracts/contract.aspx?contractid=2753>.

⁵⁶ Homer M. Brett, military historian and author *The Military Knife & Bayonet*, to the author, email, 23 March 2012.

⁵⁷ See Brayley, *Bayonets: An Illustrated History*. Also see Homer M. Brett, *The Military Knife & Bayonet* (Tokyo, Japan: World Photo Press, 2001).

bayonet in a scissors manner, forms a two-handed set of wire cutters. The same scabbard also possesses a built-in screw driver head for assembling, tightening, and repairing various pieces of equipment. With regard to the OKC3S, a honing rod is integrated into the sheath. The rod allows the soldier to sharpen the weapon while in the field without having to carry additional gear.⁵⁸

Another reason the bayonet has remained an economical option has to do with a standard mounting mechanism. US manufacturers adopted the concept of a bayonet lug after the Army had procured several hundred thousand Krag-Jørgensen rifles during the latter part of the 19th century.⁵⁹ As breach-loading weapons became the norm and ramrods were no longer required, the Norwegian-based rifles incorporated a simple T-shaped lug in the gun barrel's design. The grooved hilts of various types of sword and knife bayonets would slide over this lug and lock into position. A ring, which was integrated into one side of the bayonet's crossbar, would slip over the end of the barrel and serve as a forward attachment point. This lug-ring arrangement adequately secured the bayonet for a thrust or slash attack. Additionally, it was simple and very easy to assimilate into the designs of future firearms and bayonets. Consequently, as a result of these benefits, little to no resources had to be spent on designing new attachment mechanisms for different styles of bayonets.

Many contemporary rifles manufactured in the United States, to include the AR15, M16A2, and M4, have the standardized bayonet lug incorporated into their designs.⁶⁰ While the original purpose of this lug was to support the bayonet, the lug has become a common attachment

⁵⁸ Picture and description of M9, <http://www.ontarioknife.com/catalog/item/7>.

Picture and description of OKC3S, <http://www.ontarioknife.com/catalog/item/3>.

⁵⁹ Hardin, Jr., *The American Bayonet*, 152. Evans, *The Bayonet*, 117-119. Brayley, *Bayonets: An Illustrated History*, 227. Jamieson, *Crossing the Deadly Ground*, 133. Stieghan, interview by author, 22 March 2012.

⁶⁰ Observed guns, National Infantry Museum, visit by author, 22 March 2012. Stieghan, interview by author, 22 March 2012.

point for fixing a variety of devices to rifles. From lasers and video cameras to shortened shotguns, both soldiers and engineers have fixed numerous types of equipment to the lugs.⁶¹ The lug has supported equipment for long-term operations. It also has provided short-term attachment points for equipment that had not been adequately incorporated into gun design.⁶² Based on the alternative uses for the lug, it is highly unlikely light-firearm manufacturers will get rid of the lug and will continue to provide an attachment point for the bayonet long into the future.⁶³

Another reason why the bayonet is an economical option has to do with the cost of alternative technologies. A variety of skills and technologies may be used to harm an adversary in a close-quarters situation. Options range from combative techniques using one's hands to the use of small-caliber side arms. While hand-to-hand fighting requires little to no equipment and is cheaper, procuring and replacing higher-end technologies is typically more expensive. In comparison to the fifty-dollar M9 bayonet, the US Army's M9 pistol, minus the cost of ammunition, cost \$178.50 in 1985 and \$409 ten years later.⁶⁴

⁶¹ Observed devices, National Infantry Museum, visit by author, 22 March 2012.

⁶² "The bayonet mount is useful for mounting training devices, e.g. the MILES [Multiple Integrated Laser Engagement System] device. It also, in some designs, accommodates the mounting of a grenade launcher." Colt's Defense engineers, Colt's Manufacturing Company LLC., to the author, email, 28 February 2012.

⁶³ Additionally, it would cost more to get rid of the lug. "At this point in the design of the M16/M4, there would be a cost incurred to remove the bayonet mount." Colt's Defense engineers, Colt's Manufacturing Company LLC., to the author, email, 28 February 2012.

⁶⁴ The contract in 1985 was for 315,930 guns at total cost of \$74,762,000. United States General Accounting Office, *Pistol Procurement: Allegations on Army Selection of Beretta 9-mm. as DOD Standard Sidearm*, Report to the Chairman, Committee on Government Operations House of Representatives (Washington, D.C.: General Accounting Office, June 1986), 20. Comptroller General of the United States, *Decision: Matter of Smith and Wesson* (Washington, D.C.: General Accounting Office, 9 February 1989), 2. The contract in 1995 was for 45,096 guns at total cost of \$18,467,001. Office of the Assistant Secretary of Defense, *Contract*, Public Affairs Release 505-95 (Washington, D.C.: Department of Defense, 20 September 1995), <http://www.defense.gov/contracts/contract.aspx?contractid=625>.

Providing soldiers with equipment for bayonet training is also inexpensive. Learning how to use the bayonet does not require a significant amount of resources above and beyond what is already issued to the soldier. At a minimum, training requires the use of a firearm fixed with a bayonet. US Army and Marine Corps soldiers going through basic qualification and follow-on infantry courses are issued practice rifles to learn the basics for how to handle a firearm. As the soldier is already equipped with a firearm, the cost of an additional bayonet would depend on the type of bayonet used for training. Real bayonets, used for gaining a feel for the weapon and engaging practice targets, cost more than substitute bayonets used for sparring. During the early years of the 20th century, pieces of whale bone, covered with leather, were used for combative fencing practices.⁶⁵ These bayonets, procured as a safety measure for realistic training, were much cheaper than their combat-ready counterparts.⁶⁶

At the other end of spectrum, training may involve negotiating a course equipped with obstacles and various types of targets. However, despite entailing more requirements, the costs associated with higher-end training environments are still insignificant. Small plots of land needed for group training abound on most military installations. In the absence of a dedicated bayonet course, other training environments with a variety of obstacles and terrain may be used as an effective substitute. Building a new course is neither difficult nor expensive. Constructing vertical terrain may involve digging some trenches or constructing small hills. Walls of recycled materials, such as tires or used plywood, may be used for obstacles. With regard to targets, suitable objects for thrusting and slashing may include the bodies of dead animals, as was the practice

⁶⁵ Stieghan, interview by author, 10 March 2012. Hardin, Jr., *The American Bayonet*, 186-194.

⁶⁶ The trend is no different today. The training version of the OKC3S cost \$37.38 (USMC contract price for 2,000 bayonets). Ms. Sue Green, 2003 OKC3S contract POC, Ontario Knife Company, to the author, email, 2 2012. Picture and description of OKC3S Bayonet Trainer, <http://www.ontarioknife.com/catalog/item/5>.

of the British during the 1920s, or bags filled with sand that either hang from a rope or lie on the ground.⁶⁷

Peacetime Employment

The bayonet provides a variety of peacetime benefits at very low cost. Perhaps the most important benefit involves the psychology associated with advancing and killing on the battlefield. Bayonet training empowers a soldier to close with an enemy in combat. It fills a critical psychological gap associated with the logical progression to close-quarters combat. Every soldier understands there are a variety of reasons why he may have to close with the enemy. He may be ordered to close in the face of enemy fires, despite the risks. The enemy's defensive positions or the character of the environment may require close-quarters encounters. Finally, he may need to get close to an adversary in order to achieve surprise.

While the soldier understands he may have to close with an enemy, he also understands the limitations of the weapons at his disposal. The contemporary soldier possesses a variety of implements, ranging from rifles to grenades, for incapacitating an enemy. Many of these devices can be applied both at range and in close quarters; an M4 rifle is effective both at a distance and when the muzzle is pressed against the chest of an adversary. However, despite possessing manifold capabilities, every soldier has to embrace a fear associated with the limitations of his hardware. Should his weapon malfunction or he run out of ammunition, his capacity is usually degraded to his close-quarters potential.

The soldier who has confidence in his close-quarters abilities is better prepared to advance on the battlefield. His perceived potential in close combat allows him to overcome fears associated with the fog and friction of the battlefield. Colonel William Triplet, concerned about

⁶⁷ For examples of inexpensive training aides and suitable training environments, see War Department Basic Field Manual (FM) 23-25, *Bayonet*, 7 September 1943, 41-60.

fighting the ubiquitous “Mungos” in a future conflict, captures this concept in his interwar book *Sergeant Terry Bull*:

It stands against all reason, but it does look like a man has got to have a knife on the end of his musket before he feels like it's safe to close in. I figure that every man, whether he thinks it or not, is afraid of a jam or a miss, or not having time to reload. And reasonable or not, if your outfit *knows* they're better than the Mungos, they'll *want* to close in. That's our real job – not learning 'em bayonet fighting so they can whip the Mungos, but so they *know* they can whip the Mungos.⁶⁸

In his excerpt, Triplet attributes the confidence of soldiers to the bayonets at the ends of their rifles. However, it is not the weapons' presence that makes the soldiers want to close with the enemy but rather the *training* that gives them confidence to advance.

Based on the above argument, a case could be made for training to any type of close-quarters combat; being highly capable in hand-to-hand combat could have the same effect on one's willingness to advance on the battlefield. However, while such arguments may be valid, they may not be so convincing as the case for the bayonet. The bayonet introduces a psychological component of reach into the argument. Lt Col Dave Grossman, in his book *On Killing*, contends soldiers unconsciously desire to achieve effects as far away as possible.⁶⁹ Based on the threat of the enemy, a soldier would much rather kill at range than use a firearm at point blank range.⁷⁰ The psychology associated with distance is no different in the close quarters. A bayonet extends the effective range of the wielder further than other hand-held clubs or knives and undeniably

⁶⁸ Terry Bull [William H. Triplet], *Sergeant Terry Bull: His Ideas on War and Fighting in General* (Washington, D.C.: Infantry Journal, Inc., 1943), 20.

⁶⁹ Lt Col Dave Grossman, *On Killing: The Psychological Cost of Learning to Kill in War and Society* (Boston, MA: Little, Brown and Co., 1995), 99-106.

⁷⁰ Lt Col Grossman accounts for the effects of mechanical assistance, such as a rifle scope, in his analysis. He acknowledges that seeing the sweat bead off a targets head through a rifle scope from a mile away does induce psychological effects that differ from cases in which the shooter isn't familiar with the details of the target. Grossman, *On Killing*, 107-110.

beyond the reach of one's hands.⁷¹ Consequently, soldiers trained in the bayonet should enjoy a marginal psychological advantage over their hand-to-hand fighting counterparts.

Bayonet training also enables a soldier to *kill* in the close-quarters environment. While shooting an individual at a distance is somewhat impersonal, sticking "cold steel" *into* another human is not. Killing in-close is a complex affair.⁷² Closely intertwined with the concept of reach is one's desire or capacity to kill. Lt Col Grossman further argues a soldier's resistance to killing is a function of the distance between the soldier and his intended target.⁷³ The rifleman, a mile away from his target, struggles less with the idea of killing than the soldier sticking a bayonet into an adversary. This argument does not suggest the rifleman is less affected by killing but rather less hesitant when it comes time to pull the trigger.

While killing at closer ranges is difficult, the transition from firing a weapon to piercing a human body is especially complicated. There is a psychological barrier associated with penetrating an adversary's body with a weapon.⁷⁴ Combatants have historically been reluctant to use the bayonet in the manner for which it was designed. Rather than thrusting the weapon into the enemy and guaranteeing a fatal strike with one

⁷¹ The more logical counterargument to the bayonet-tipped rifle would be the use of a pistol. However, as with the sword bayonets, pistols are not issued to every soldier. They are more commonly issued to positions of rank and to forces with specialized qualifications. For example pistols are often issued to snipers, special-forces troops, and artillerymen. CSM Jeffrey Dillingham (15th Infantry Branch, 3rd Battalion, 4th Infantry Brigade Combat Team, 3rd Infantry Division, Fort Stewart, GA), interview by author, 22 March 2012. Maj Stephen P. Kahn (former Weapons Company Commander, US Marine Corps), interview by author, 24 May 2012.

⁷² It is less of a complex affair when the enemy is routed and is running away. Personalizing the target has much to do with the ability to kill. Lt Col Dave Grossman and Loren W. Christensen, *On Combat: The Psychological and Physiology of Deadly Conflict in War and in Peace*, (United States: PPCT Research Publications, 2004), 194-199.

⁷³ Grossman, *On Killing*, 97-99. Joanna Burke, *An Intimate History of Killing: Face-to-Face Killing in Twentieth-Century Warfare* (London, UK: Granta Books, 1999), 155-190.

⁷⁴ Grossman, *On Killing*, 114-133.

application of force, bayonet equipped soldiers have most often beaten, hacked, and sliced their adversaries to death.⁷⁵

Bayonet training is an effective tool for addressing the reluctance to kill. It is designed to overcome the psychological challenges of the battlefield. Training many times produces automatic responses to certain stimuli and helps overcome barriers to action.⁷⁶ Not acting in a programmed manner could have dire consequences. Hesitation due to a resistance to kill in close combat may result in the adversary having the initiative and the soldier ending up the victim.⁷⁷ A soldier who slashes when the situation requires a thrust provides opportunities for the enemy to change the tide of events. In light of the many small but lethal technologies on today's battlefield, even a wounded adversary should be considered dangerous. Consequently, the soldier in his approach to kill a wounded adversary is vulnerable. Further complicating his vulnerability are situations in which the soldier must engage other adversaries prior to killing his original target.

Aside from the psychological benefits associated with training, the practical and logical character of modern bayonet training techniques optimizes the soldier's capabilities in the combat environment. As in earlier times, the gun remains the soldier's primary weapon on the battlefield. In light of the rifle's importance, the soldier's close-to-kill

⁷⁵ Grossman, *On Killing*, 114-133.

⁷⁶ Burke, *An Intimate History of Killing*, 69-102. Capt Lawrence E. Sommers, "Retention of the Bayonet" (faculty advisor paper, Fort Benning, GA: US Army Infantry School, 24 June 1974), 7. Anthony Kellet, *Combat Motivation: The Behavior of Soldiers in Battle* (Boston, MA: Kluwer Publishing, 1982), 324-325. Lt Col Bell I. Wiley, *Training in the Ground Army: 1942-1945*, Study 11 (Fort Monroe, VA: Army Ground Forces: Historical Section, 1948). While the effectiveness of realistic training has been debated, veteran Marine Corps drill instructors still uphold the concept and contend "a lot of young men arrive in boot camp without ever having been in a fight, without ever balling up their fists and hitting another person." Drill instructors argue that through training, "They [the new recruits] stop being afraid of hitting someone and of being hit." Tony Perry, "Marines do About-face on Injuries: Corps Hires Athletic Trainers to Help Boot Camp Recruits," *Chicago Tribune*, 11 Nov 2011. Perry's comments are in line with the actions of soldiers in war after they had survived a fearful experience. See Kellet, *Combat Motivation*, 299-300.

⁷⁷ Grossman, *On Killing*, 154-171.

capabilities depend on his capacity to load, aim, and fire the gun while he maneuvers, both for offensive and defensive purposes. Much of his effectiveness has to do with the orientation of the firearm and the amount of time the rifle is in the soldier's hands. Modern training techniques focus on these principles while highlighting the utility of the bayonet in situations where the effects of the rifle are negated.

Contemporary US Marine Corps instruction demonstrates a pragmatic approach to bayonet training. The soldier fixes his bayonet at the outset of an expected close engagement. As a soldier closes, both of his hands are affixed to the rifle. His rifle is always aimed at his intended target. He maintains a body position that balances his exposure to the enemy against his ability to maneuver. The soldier fires as desired and minimizes his vulnerability during reloads. If the soldier is able to close with enemy or is attacked while he is reloading, he lunges forward, discharges his firearm if able, and thrusts his rifle and attached bayonet into the enemy. If he is attacked from the opposite direction while he is completing a kill, he pulls the bayonet out and maneuvers the butt of his rifle in the opposite direction to strike the adversary or goes over the top with the bayonet in the opposite direction. At no time does he change the locations of his hands on the rifle, nor does he remove them, unless to reload. The soldier is always in position to quickly transition back to the use of his firearm, either for long range or close effects.⁷⁸

Based on this relationship between the soldier and his firearm, training with the bayonet may be more advantageous than training to other technologies and close-combat techniques. Whereas training with the bayonet requires the soldier to maintain contact with the rifle, many close-quarters technologies and combative techniques involve removing one's hands from the rifle or dropping the weapon completely.

⁷⁸ See Mgy Sgt Shane T. Franklin, "The Need for Bayonet Training in the 21st Century," *Marine Corps Gazette*, June 2008, 31-33.

Programming soldiers to get rid of their primary weapons in favor of alternative technologies and techniques is problematic for a variety of reasons. Dropping a rifle to employ a pistol or to engage in hand-to-hand combat increases the time required to transition back to the primary weapon. During the time it takes him to reacquire and reorient his rifle, he is now at the mercy of the long-range fires of the adversary. The problem is worse when the soldier is unable to find his weapon or the enemy is able to gain control of the firearm. In some situations, the adversary may be able to use the previously discarded rifle against the soldier.

Though training with the bayonet is beneficial for a variety of reasons, it does come with a cost: *time*. While bayonet training may efficiently be incorporated into rifle training and field maneuvers, as is the case with the US Marine Corps model, the time devoted to every activity involving the bayonet is much more than the time required for employing the bayonet on the training course. Time is required to accomplish a number of activities that range from drafting training documents and giving additional safety briefs to cleaning, storing, and accounting for the equipment.

Today's soldier is much more capable than Triplet's version. He has to learn many more skills than hand-to-hand combat, bayonet fighting, and shooting his rifle. Though many senior military leaders extol the virtues of bayonet training, they cannot justify the weapon's time requirements when compared to the other training requisites.⁷⁹ In 2009, the time associated with an updated set of requirements necessitated cutting 140 hours of outdated training time from the US

⁷⁹ "General: Drop Bayonet from Military Training," *Military.com News*, 28 January 2010, <http://www.military.com/news/article/general-drop-bayonet-from-army-training.html>. Jim Garamone, "General Discusses Changes to Initial Army Training," *Defense.gov News*, 23 September 2010, <http://www.defense.gov/news/newsarticle.aspx?id=60982>.

Army soldier's indoctrination course.⁸⁰ As the last US-led bayonet charge had not occurred since the Korean War and the bayonets had not been fixed in combat for some time, senior Army leadership elected to eliminate the training within the service.⁸¹ The US Marine Corps, based on its training model and an assessment of the bayonet's benefits in combat has yet to follow in the Army's path.⁸²

Wartime Employment

The bayonet has numerous wartime benefits. One benefit is the result of the environments in which soldiers have operated. As stated before, the modern soldier understands there are times when he will have to close with the enemy. A major factor in his calculation is the character of the environment in which he operates. The adversary's position in relation to terrain, vegetation, and man-made obstacles determines the likelihood of a close quarters encounter. Whereas the conditions of the Western Front during World War I made it unlikely for a soldier to engage in close combat, this has not proven to be an absolute in modern warfare.

⁸⁰ Maj Ryan S. Reid (student, SAASS), in discussion with author, 20 February 2012. Maj Reid was formerly the 23rd Quartermaster Brigade Operations Officer, US Army Quartermaster Center & School, Combined Arms Support Command, Army Training and Doctrine Command. His comments stem from an Individual Military Training conference hosted by Lt Gen Mark Hertling, October 2009.

⁸¹ Though the latest Army field manual for Combatives, FM 3-25.150, 2002, still shows the use of the bayonet, edged weapons are not being used in the Modern Army Combatives Program at this time. See information on courses, US Army Maneuver Center of Excellence, 197th Infantry Brigade, Combatives School, <https://www.benning.army.mil/infantry/197th/combatives/index.html>. Also see Maj Shane M. Carpenter, "The Right Mindset for Comprehensive Soldier Combatives," (master's thesis, Army Command and General Staff College, 2010), 90. This was not the first time the Army did away with bayonet training. The Army cancelled the training in the early 1970s and brought it back a decade later in 1981. "Army Resumes Bayonet Training: Infantry Training Extended 6 Hours for Basic Moves," *New York Times*, 7 November 1981.

⁸² Marines, "from the Commandant to the newest recruit, male and female alike, are required to receive the Marine Corps Martial Arts Program training," where bayonet and knife-fighting techniques are taught. Harold Kennedy, "Marines Sharpen Their Skills in Hand-to-Hand Combat," *National Defense*, November 2003. For an example of current training see "Intense Course Trains Marines in Martial Arts," *Military.com News*, 10 August 2011, <http://www.military.com/news/article/marine-corps-news/intense-course-trains-marines-in-martial-arts.html>.

US soldiers have engaged adversaries in a variety of environments that favored intimate encounters. In World War II and Korea, soldiers on both sides dug, hid in, and explored “fox holes.”⁸³ The jungle environment and man-made caves of Vietnam regularly brought opposing soldiers within arm’s reach of one another.⁸⁴ Soldiers engaged in urban warfare in Iraq and Afghanistan repeatedly dealt with threats that lurked around every corner.⁸⁵ In each of these environments, the bayonet in many cases provided a compelling psychological benefit through an enduring source of reach and lethality.⁸⁶

Dovetailed with the environment is the bayonet’s silent and less visible character. There are times when soldiers will have to close with the enemy to achieve surprise.⁸⁷ Though advancements in flash and

⁸³ Kenneth Steele, “Face to Face with the Enemy: A Survivor’s Tale from the Wrong end of Japanese Bayonet on Iwo,” *Marine Corps Gazette*, December 2005.

⁸⁴ Robert J. Berens, “The Bayonet: Simple but Dependable,” *Infantry*, May-June 1988.

⁸⁵ In many cases the threats are in tunnels below ground. Stew Magnuson, “Daunting Challenges Face Those Waging Subterranean Warfare,” *National Defense*, February 2007.

⁸⁶ Much of why the bayonet is useful in these environments has to do with the weapon’s evolution since the US Civil War. Military leaders pursued versions of the bayonet that favorably balanced the bayonets’ intended purposes against the environments in which the soldier operated. With the more secure attachment mechanisms the United States adopted the knife-style bayonet. Though they were shorter and had less reach than sword bayonets, they were easier to wield as a hand-held tools and weapons. Earlier knife bayonets were roughly eleven inches long. As firearm technology progressed, and the barrels of various guns were shortened, military leaders sought longer blades. Bayonet lengths grew to embrace 16 and 17-inch blades. The character of trench warfare and the diminished importance of cavalry, however, led leaders to again shorten the bayonets. Shorter knives, when detached from the rifle, would be more balanced and better suited for hand-to-hand fighting and would allow soldiers to attach the weapons to their belts. The M1 bayonet, with a ten inch blade, was the standard bayonet used throughout World War II. The M4 bayonet employed throughout the Korean War had a blade length of seven inches. Both the M6 bayonet utilized during the war in Vietnam and the M7 bayonet, designed for the AR-15 and M16, sported seven-inch blades. The blades of the previously mentioned M9 and OK3CS bayonets are seven and eight inches, respectfully.

⁸⁷ Japanese soldiers regularly snuck up on unsuspecting victims during World War II. Kenneth Steele, “Face to Face with the Enemy: A Survivor’s Tale from the Wrong end of Japanese Bayonet on Iwo,” *Marine Corps Gazette*, December 2005. War Department, *Japanese Tactics on Guadalcanal*, Tactical and Technical Trends Report 21 (Washington, D.C.: US Military Intelligence Service, 25 March, 1943). There were continuous night attacks with the bayonet on Lone Tree Hill during the Russo-Japanese

sound-suppressor technologies have increased the standoff capabilities of firearms, sometimes the character of the environment and enemy positions prevent the use of a firearm or warrant less visible or more silent attacks. In these instances the bayonet has been an extremely effective weapon. Fixed bayonets have proven particularly useful for hit-and-run stabbings while keeping out of the enemy's reach.⁸⁸ When the environment prevents maneuvering with the bayonet in the fixed position, the soldier can detach the weapon and still maneuver to complete the kill.

Perhaps the most important benefit the bayonet provides during wartime involves psychology on the battlefield. The bayonet intimidates. While soldiers are averse to using a bladed weapon to penetrate another human being, they are also naturally fearful of befalling the same misfortune.⁸⁹ This condition is based on familiarity with the pain associated with a cut or puncture wound. Most humans, either through accident or by intention, have seen or felt the effects of sharp-edged objects.

Closely tied with the soldier's familiarity is the weapon's presence throughout an engagement. As an enduring image, the bayonet produces psychological effects very different than those produced by a firearm. While munitions travel at speeds that essentially make them invisible, the bayonet is evident from the time it is fixed on the battlefield until it is thrust into an adversary's body. Based on the relative speed of the bayonet, a soldier is better able to comprehend what his death will be

War. Charles T. Payne, "The Russo-Japanese War: Impact on Western Military Thought Prior to 1914" (master's thesis, Athens, GA: University of Georgia, 1990), 47.

⁸⁸ A more dated example occurred during America's Revolutionary War. 150 Americans were bayoneted by British soldiers while they slept by their camp fires. Sprague, *A History of Edged Weapon Warfare*, 315. Michael D. Schaffer, "Night Bayonet Attack Sent Americans Reeling," *The Philadelphia Inquirer*, 15 September, 2002.

⁸⁹ "Once when I had a bayonet a few inches from my belly I was more frightened than by any shell." Lord Moran, *The Anatomy of Courage: The Classic WWI Account of the Psychological Effects of War* (New York, NY: Carroll & Graf Publishers, 2007), 75. American Veterans of the International Brigades reported they were more fearful of the bayonet and knife than machine guns and tanks. Kellett, *Combat Motivation*, 255.

like. Whereas the effects of a rifle are instantaneous and promise a quick death, contact with the bayonet does not. Consequently, a soldier is more apt to flee in the bayonet's presence than when faced with a rifle or pistol.⁹⁰

The ability to produce psychological effects on the battlefield has been the bayonet's mainstay. Throughout the weapon's existence there has been little historical evidence to support the bayonet's utility as a decisive killing instrument on the battlefield. Many leaders, administrators, and medical corps personnel, who have observed and recorded the numbers and types of wounds on the battlefield, have concluded the bayonet plays a minor role in killing.⁹¹ However, what they fail to acknowledge is the bayonet's utility *while* closing with the enemy.

The bayonet has been beneficial as an intimidator on the battlefield, particularly during advancements. History, prior to the US Civil War, abounds with examples of bayonet charges and adversaries fleeing in their presence. However, the last hundred years also provide instances in which fixed bayonets led to successful assaults on the enemy. The most recent US example was Captain Lewis L. Millett's assault up a North Korean-held hill on 7 February, 1951. During the engagement, he ordered his platoon forward and led them in a fixed-bayonet charge. "They stormed into the hostile position and used their bayonets with such lethal effect that the enemy [equipped with small

⁹⁰ Moran, *The Anatomy of Courage*, 75. Kellett, *Combat Motivation*, 255.

⁹¹ As with the ram, the bayonet would be widely debated following the Civil War. Much of the debate had to do with actual combat results. Recorded observations showed very few deaths resulted from bayonet stabbings. However, what the results did not show, and what bayonet advocates argued, were the psychological effects the weapon had on the battlefield. Soldiers often froze or ran in the presence of a bayonet charge. On the other hand, fixing bayonets motivated infantrymen to hold ground or move forward while in the presence of enemy fires. While actual bayonet *fighting* was less common, the standoff effects of the bayonet and/or bayonet charge were not. Nosworthy, *The Blood Crucible of Courage*, 594-608. See also Jamieson, *Crossing the Deadly Ground*. Grossman, *On Combat*, 199.

arms, automatic, and antitank weapons] fled in wild disorder.”⁹² A more contemporary case involved British forces in Iraq. “In May 2004, approximately 20 British troops in Basra were ambushed and forced out of their vehicles by about 100 Shiite militia fighters. When ammunition ran low, the British troops fixed bayonets and charged the enemy. About 20 militia men were killed in the assault without any British deaths.”⁹³

Much of the success of these charges likely has to do with two factors. Fixed bayonets probably shocked the adversaries and provided a degree of surprise. According to some accounts, Millett’s charge was so out of the ordinary that North Korean soldiers were unable to comprehend the context of the situation and froze while they attempted to analyze what was going on.⁹⁴ The charge also provided moments of panic and fear as the adversaries realized the bayonet-equipped soldiers were determined to resolve their affairs with the bladed weapons.⁹⁵ In some cases, these conditions caused debilitating effects where the enemy was unable to act. In other instances, the enemy fled, often with their loaded rifles still in hand.

The bayonet has also served as a useful motivator for individual and groups of soldiers. In contemporary warfare, the order to “fix bayonets” conveys a unique set of circumstances. The fixed bayonet means the “shit has hit the fan” and that soldiers must be extra vigilant

⁹² Captain Millett was posthumously awarded Congressional Medal of Honor. Citation, <http://www.cmohs.org/recipient-detail/3158/millett-lewis-1.php>. “Battleground Korea: The Story of the 25th Infantry Division,” ed. Capt Allen A. David and Sgt Norwin E. Austin (Schofield Barracks, HI: 25th Infantry Division History Council, 1951).

⁹³ Edwin Halpain and Justin Walker, *Bayonets in Basra – A Case Study on the Effects of Irregular Warfare*, Urban Warfare Analysis Center report (Shawnee, OK: US Army Research Laboratory, January 2009), 3.

⁹⁴ Jefferson C. Reed (arms curator, National Infantry Museum, Columbus, GA), interview by author, 22 March 2012.

⁹⁵ Though the bayonet was not historically a new weapon, its presence in contemporary battles had the same effects as when a new technology is introduced in combat. Gay M. Hammerman, Brian Bader, Trevor N. Dupuy, and Charles R. Smith, *Human Impact of Technological Innovation on the Battlefield*, US Army Medical Research and Development Command Report 114 (Dunn Loring, VA: T.N. Dupuy Associates, Inc., March 1985). Between World War I and Vietnam, the authors noted there is often sense of panic that results from the introduction of a new weapon on the battlefield.

in how they assess their environment and employ their weapons. It sends the message that there is a significantly increased chance for close-quarters combat. Finally, when the order to fix bayonets has been followed by a command to “charge,” the bayonet unites individuals into a cohesive whole able to advance in the face of extremely unfavorable odds.⁹⁶

Both the previously mentioned examples in Korea and Iraq embody the motivational power of the bayonet. However, there are examples that did not involve a bayonet charge. In Vietnam, Lt Col Robert C. Prewitt, commander of Company B, 1st Battalion, 7th Marines, and his men were in an isolated position surrounded by North Vietnamese Army forces. Unable to make contact with friendly forces, Lt Col Prewitt and his men defended their position for an extended period of time and consequently started to run out of ammunition. As “each man had only a handful of bullets left...and knew they were in a fight for their lives,” the colonel unexpectedly ordered the men to “Fix Bayonets!”⁹⁷ The order sustained the soldiers until they were resupplied hours later.

Though much has been said about the bayonet’s psychological utility in wartime situations, little has been mentioned with regard to use of the weapon in relatively peaceful environments. There are times in war, and hostile situations in times of peace, when noncombatants become the threat. During these times, the bayonet again provides a psychological benefit for the soldier. When fixed, the blade becomes an immediate form of deterrence. Civilians, either individually or gathered together in a mob, analyze the character of the weapons they will have to overcome or circumvent in order to affect or bypass soldiers. Whereas shields and short clubs are less menacing, and are perceived as an

⁹⁶ Nosworthy, *The Blood Crucible of Courage*, 598-601.

⁹⁷ Lt Col Robert C. Prewitt, “Fix Bayonets!: An Understrength Marine Rifle Company Comes Face to Face with the Enemy Main Force during the early stages of the Vietnam War,” *Marine Corps Gazette*, February 2006.

escalatory measure for crowd control, the bayonet's presence is far more extreme and promises that much more pain will have to be endured to achieve desired effects.

Soldiers have long used fixed bayonets for crowd control. They have fixed bayonets in times of peace and war. Most recently, US soldiers in 2003 fixed bayonets in response to a mob forming in downtown Baghdad.⁹⁸ Members from the 3rd Infantry Division were given the order in response to the crowd's increasing threat. Though the soldiers were carrying highly capable M4 carbines, the civilians understood the limitations associated with the soldiers wielding the firearms.⁹⁹ Based on rules of engagement and US desire to limit civilian casualties, it was far more detrimental for the soldiers to fire into the crowds than for the mob to close with them. However, fixed bayonets changed the equation. Once the soldiers attached the weapons, the onus was placed on the combatant. He would have to engage the bladed barriers to press closer. Additionally, should the soldier elect to attack a civilian, physical harm could be done without killing. As the likely result of these assessments, the crowd promptly disbursed.¹⁰⁰

As with training during peacetime, the bayonet provides a variety of benefits in wartime or hostile situations, but it comes with a cost. Perhaps the greatest cost comes in the form of alternative weapons and technologies. As alluded to before, there are other desirable technologies that can be fixed to lugs of modern rifles. Many of these technologies increase the range, number, and variety of effects the soldier is able to deliver. Unfortunately, fixing these technologies to the bayonet lug in many instances prevents the soldier from being able to use the bayonet.

⁹⁸ Reed, interview by author, 22 March 2012.

⁹⁹ The crowds were also likely conditioned to the M4's presence and were less affected by its presence. Kellett, *Combat Motivation*, 255.

¹⁰⁰ Reed, interview by author, 22 March 2012.

In the case of the M203 grenade launcher, fixing the weapon to the rifle prevents anything else from being fixed to the lug.¹⁰¹

Conclusions

Unlike the ram, there is still value in the bayonet. Whereas the modern warship carries large amounts of munitions and supplies, today's "Army of One" does not. It is still possible to run out of standoff effects, either as a result of being outnumbered by the enemy or not being able to carry enough ammunition. In some situations, rules of engagement may preclude the use of longer-range weapons. When you're in close, out of bullets, and need to be quiet the bayonet provides a variety of enduring effects at an affordable price.

Furthermore, the environment surrounding the soldier is less defined than that above and below the water. There are ample opportunities for a soldier to close with an adversary. Though standoff detection capabilities are evolving on a daily basis, there still are many places for an adversary to hide. For example, unmanned aerial systems are often limited by the small fields of regard and Joint Surveillance Target Attack Radar System technologies are unable discriminate between friendly, civilian, and enemy ground forces. Until these uncertainties are resolved, and the promise of close encounter further wanes, the bayonet will retain value.

As with the ram, it is necessary to highlight peculiar psychological behaviors with respect to bayonet. Particularly noteworthy is the disparity between the services in the US armed forces. Whereas the US Army has abandoned the bayonet twice in recent times, the weapon has been an icon in the US Marine Corps. Given the similarities in the two service's practices, it is difficult to understand why they would have

¹⁰¹ Colt's Defense engineers, Colt's Manufacturing Company LLC., to the author, email, 28 February 2012. Observed gun-device interface, National Infantry Museum, visit by author, 22 March 2012.

chosen different paths. Perhaps the US Army soldier finds comfort in the size of the organization and believes the guns of his more numerous fellow soldiers will support him should his ammunition run out.¹⁰² The US Marine, believing he is part of smaller organization, may be unable to embrace such logic.



¹⁰² The 2011 end strength for the US Army was 569,400 soldiers. The end strength for the US Marine Corps was 202,100. United States House of Representatives, *National Defense Authorization Act for Fiscal Year 2012*, Report on H.R. 1540 (Washington, D.C.: House of Representatives, Committee on Armed Services, 17 May 2011), 144.

Chapter 3
Giving up the Gun?
A Romance for Fighter Aircraft

I don't want to take too much away from missiles; they are wonderful for bomber destruction. They're wonderful in certain types of air fighting, but I don't ever want to get caught without a gun, without the final capability to close when I'm really in there.

*Lieutenant General Arthur C. Agan
Commander, USAF Aerospace Defense Command*

Since the inception of the airplane, political and military leaders have wrestled with the promises of air power and debated the roles of aircraft over the battlefield. Imbedded in many of these arguments have been discussions surrounding the suitability and feasibility of various forms of aircraft armaments for close-quarters combat. With regard to fighter aircraft, the gun has become a major source of contention. The gun, like the ram and bayonet, extends the operator's reach. However, rather than being connected to the operator, the utility of the weapon depends on the metal "swords" formed by a volume of bullets traveling at thousands of feet per second.

As concepts of air warfare have evolved, fighter guns have changed in number, placement, form, and function. Early versions of guns were affixed to fighter aircraft in a variety of manners and were serviced and employed in a number of ways. Later these guns were incorporated into aircraft design, and internally mounted weapons became the norm. As alternative technologies matured and nuclear warfare changed the character of the battlefield, the primacy of the internal gun waned and it was abandoned on multiple occasions. These notions were short lived, however, and the gun reemerged in the form of a podded variant. Ultimately, based on the cries of fighter pilots, the gun would again be integrated into fighter designs as something more than an appendage, but debates over the utility of the weapon would continue. Of note, the

Air Force's most recent air superiority fighter, the F-22, sports an internally mounted cannon. However, two of the three variants of the Department of Defense's newest fighter, the F-35, do not. The reasoning behind these designs is both complex and contentious, while the phenomenon brings into sharp focus and poignant relevance many of the themes explored in the first two cases.

The potential of the gun took root when Lieutenant Jacob Fickel, a US Army infantryman, first fired a rifle from his single-seat Curtiss biplane on 20 August 1910.¹ Though Fickel's action had been directed at a ground target, air-to-air visionaries saw the aircraft-weapon combination in a different light. Soon machine guns were being fixed to airplanes. The first trials of a machine gun on an aircraft took place on 2 June 1912, just two years after Fickel's feat.² The age of the gun-equipped fighter was born.

Placing guns on early aircraft, however, was an extremely tricky business. While Fickel's test was viewed by many as a success, the challenges associated with lifting and employing a lightweight rifle in the air did not compare to those associated with more sophisticated weaponry. Early airplanes were underpowered and fairly fragile.³ As aircraft engine technologies were still in their infancy, they were heavy and unable to generate enough horsepower to lift much more than the aircraft and its operator.⁴ Until lighter and/or more powerful engines

¹ Anthony G. Williams and Emmanuel Gustin, *Flying Guns: World War 1, Development of Aircraft Guns, Ammunition and Installations, 1914-1932* (Shrewsbury, UK: Airlife Publishing Ltd., 2003), 41-42.

² Tim Lamming and Jeremy Flack, *80 Years of Air to Air Combat* (London, UK: Kiln House, 1996), 9.

³ Louis Bruchiss, *Aircraft Armament*, ed. Glenn D. Angle (Lexington, NY: Aerosphere, Inc., 1945), 14. The purpose of Fickel's test was to ensure the recoil of his infantryman's rifle would not break up the aircraft.

⁴ Airplanes used during the 1st Aero Squadron's operations in Mexico, during the Punitive Expedition of 1916, "were already overburdened just carrying a pilot, observer, personal equipment, and a full load of gasoline. The weight of even an air-cooled Lewis machine gun would have reduced performance to an unacceptable level." Roger G.

were developed, aircraft designers achieved economy by making airframes as light as possible. Consequently, structural integrity was often sacrificed in pursuit of performance.⁵

Based on the above challenges, the United States was slow to engage the concept of a gun-equipped fighter. The growing potential for war, however, changed the calculus for many European nations. Leading up to World War I, the promises of airpower caused European countries to pursue aircraft and engine design in earnest.⁶ Aircraft, accordingly, advanced in performance and capability. Lighter and more powerful engines propelled more structurally sound aircraft through the air and were able to lift significantly heavier payloads.⁷ Aircraft, supporting two airmen and carrying heavier and more capable guns, maneuvered with greater ease than their earlier, more primitive, counterparts.

However, the more significant advancements came about as airpower leaders defined the role of the fighter. At the outset of WWI, the airplane's primary purpose was to observe the enemy from the air and subsequently inform ground forces on the character of the battlefield.⁸ Though many aircraft were equipped with some type of gun, the weapon

Miller, *A Preliminary to War: The 1st Aero Squadron and the Mexican Punitive Expedition of 1916* (Washington D.C.: Air Force History and Museums Program, 2003), 15.

⁵ Eric and Jane Lawson, *The First Air Campaign: August 1914 – November 1918* (Conshohocken, PA: Combined Books, Inc., 1996), 32-34. To get a feel for how fragile these early aircraft were, see *The Logbook of Signal Corps No. 1: The U.S. Army's First Airplane*, ed. Meghan Cunningham (Washington, D.C.: Air Force History and Museums Program, 2004).

⁶ European manufactures struggled to find suitable sources of power. In 1917, "Britain was manufacturing or experimenting with thirty-seven different service engines, and France with forty-six more." James J. Hudson, *Hostile Skies: A Combat History of the American Air Service in World War I* (Syracuse, NY: Syracuse University Press, 1968), 15. Frank Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force, 1907-1964* (Maxwell AFB, AL, Air University, 1974), 9.

⁷ Lamming, *80 Years of Air to Air Combat*, 10.

⁸ Futrell, *Ideas, Concepts, Doctrine*, 8-9. In 1913, Billy Mitchell told committee members (House Military Affairs) that although "the offensive ability the airplane had yet to be proven...the airplane was effective in its role of observation." Roger G. Miller, *Billy Mitchell: Stormy Petrel of the Air* (Washington D.C.: Office of Air Force History, Air Force History and Museums Program, 2004), 4.

was primarily used for self-defense. It was not until leaders “demanded the development of a capability to *deny* the enemy the ability to spot a buildup for an offensive from the air,” that the development of fighter aircraft blossomed.⁹ The airplane’s primary purpose now involved supporting ground forces through non-lethal and lethal means.

World War I airmen struggled with the “art” of killing in the air. Achieving deadly effects in aerial combat depended on a variety of factors, many of which were out of the airmen’s control and maturing at the same rate as leaders’ conceptual understanding of airpower. In reality, shooting down enemy aircraft depended on the quality of the pilots, aircraft, guns and ammunition; and a bit of luck. Of these factors, airpower leaders perhaps had more control over technical than human factors.¹⁰

From the very beginnings of aerial combat, killing largely depended on aircraft flight characteristics. Airplanes able to fly faster or climb, turn, and dive better than the enemy aircraft could maneuver into relative positions where armament could produce decisive effects. Performance hinged on an aircraft’s engines, structural integrity, and aerodynamic shape.¹¹ Unfortunately, leaders during the war were more focused on “the carriage of weapons rather than speed or maneuverability.”¹² Consequently, aircraft design matured at a snail’s pace throughout the war.

Gun technology, however, underwent significant changes between 1914 and 1919. Though the *concept* of a gun on an aircraft was alive

⁹ Lee Kennett, *The First Air War: 1914-1918* (New York, NY: Simon & Schuster, 1991), 64.

¹⁰ “As aircraft and pilots were in high demand throughout the war, in-depth training was often sacrificed in support of getting aircraft into theater. As the war progressed, and the stockpile of resources grew, the amount and quality of aircrew training progressed. Kennett, *The First Air War: 1914-1918*, 30. Cecil Lewis, *Sagittarius Rising* (London, UK: Frontline Books, 2009), 30.

¹¹ I. B. Holley, Jr., *Ideas and Weapons* (New York, NY: Yale University Press, 1953), 121-123.

¹² Lamming, *80 Years of Air to Air Combat*, 11.

and well at the outset of WWI, the practical application of the idea was not. Early airmen, much in line with Lt Fickel's reasoning, resorted to hand-held rifles and side arms for aerial combat.¹³ Other pioneers equipped "back-seaters" with flexible machine guns capable of firing in many directions.¹⁴ Unfortunately, these initial cadres of airmen and weapons were unable to achieve the rates of fire required to down an aircraft in a dynamic flight environment where accelerations in three dimensions made it extremely difficult to hit a target.¹⁵

As airmen continued to engage in aerial gunnery, it became evident that forward-firing guns were required to down an enemy in a mature turning engagement. Killing depended on opposing aviators' maneuvers, and it made sense to orient gun fires in the direction the pilot was

¹³ Williams, *Flying Guns: World War 1*, 44-47. Bruchiss, *Aircraft Armament*, 13-14. Stephen Budiansky, *Air Power: The Men, Machines, and Ideas that Revolutionized War, from Kitty Hawk to Iraq* (New York, NY: Penguin Books, 2004), 62.

¹⁴ The quality of guns and ammunition did not change much throughout World War I. The majority of guns fixed to aircraft were machine guns transplanted from the ground fight. Guns were classified in terms of being "fixed" or "flexible." Fixed guns were secured and could not be moved during flight; they had preset fields of fire. The advantage of the fixed gun was it was bore-sighted on the ground and remained so throughout flight. The disadvantage of the gun resulted from it becoming dependent on the orientation of the aircraft; a fixed-gun fighter with an adversary on its "six" had no offensive capabilities. The flexible machine gun accounted for this disadvantage. Flexible machine guns depended on various mounts and attachment mechanisms that made it easy to move the gun around while still being secured to the aircraft. The disadvantages of these weapons were the degree of accuracy that was lost as the weapon was not fixed from takeoff to landing. Williams, *Flying Guns: World War 1*, 31-33, 47-74. Bruchiss, *Aircraft Armament*, 15. The British Vickers and German Spandau and Parabellum guns were the common machine guns fixed to Allied and Central Powers fighters. The Parabellum was a modification of the Spandau machine gun. The Spandau had a water-filled jacket that surrounded the barrel of the gun. The jacket served to cool the barrel during fire, helping to preserve the integrity of the barrel and service life of the weapon. The Parabellum achieved the same benefits by punching numerous holes in the jacket and cooling the gun by air rather than water. This was more feasible for guns traveling through the air and saved considerable weight. "Nonnuclear Aircraft Armament The Evolution of Aircraft Guns, 1912-1945," by David R. Mets, 1987, pp. 9-22, Call # 243.04-57 C.1 1 Jan 1912 - 31 Dec 1945, IRIS # 01083438, USAF Collection, AFHRA, Maxwell AFB AL.

¹⁵ David R. Metts, *Checking Six is Not Enough: The Evolution and Future of Air Superiority Armament*, CADRE Paper Special Series: The Future of the Air Force, no. AU-ARI-CPSS-91-14 (Maxwell AFB, AL: Air University Press, April 1992), M-U 37097-39 no. 91-14, MSFRIC, 3-4.

maneuvering his airplane.¹⁶ Doing so allowed him to keep his hands on or closer to the controls and better oriented in relation to his flight path and intended target and ultimately allowed him to take advantage of the small windows of opportunity that were the norm in aerial combat.¹⁷ Additionally, forward-firing guns eliminated the need for a rear gunner. Not having the requirement for an additional body saved weight and, in turn, enhanced the airplane's maneuverability and, when desired, allowed for the carriage of other important items, such as gas and ammunition.¹⁸

Yet, forward firing guns presented a variety of challenges. Perhaps the most noteworthy challenge involved avoiding the airplane's propeller. Airmen assumed varying levels of risk with regard to dealing with the prop. To *ensure* the pilot did not shoot off a major source of the aircraft's power, machine guns were placed above or to the side of the propeller's arc.¹⁹ Regrettably, the placement of these guns often required a pilot to stand up or exit the cockpit to reload or service a jammed weapon.²⁰ Such practices were extremely hazardous in the dynamic aerial environment, where flying the aircraft took precedence over employing weapons. When airmen were willing to assume more risk, machine guns were placed closer to the cockpit and aimed and fired through the propeller.²¹ To protect the prop against an inadvertent strike, the props were covered in linen or metal.²² Though France's Roland Garros nearly became the first ace of the war by fixing steel plates to the leading edges of his aircraft's propeller, the dangers of such measures were obvious.²³

¹⁶ Budiansky, *Air Power*, 63.

¹⁷ Lewis, *Sagittarius Rising*, 168.

¹⁸ Metts, *Checking Six is Not Enough*, 2. Budiansky, *Air Power*, 62-63.

¹⁹ Bruchiss, *Aircraft Armament*, 13-14

²⁰ Lewis, *Sagittarius Rising*, 168. Metts, *Checking Six is Not Enough*, 4. Lawson, *The First Air Campaign*, 67-68.

²¹ Bruchiss, *Aircraft Armament*, 13-14

²² Metts, *Checking Six is Not Enough* 4.

²³ Bruchiss, *Aircraft Armament*, 15. Lawson, *The First Air Campaign*, 68-69.

The advent of a synchronizing gear made it possible to safely fire the gun in close proximity and directly parallel to the longitudinal axis of the aircraft. Through the use of an interrupting gear, a machine gun's fires were synchronized with the position of the propeller. When the pilot squeezed the trigger, the synchronizing gear ensured the gun's bullets traveled through the prop's arc in between the blades.²⁴ Though multiple countries had been working on like mechanisms, the Germans were the first to capitalize on the gear; beginning in the summer of 1915 a fleet of 400 German Eindeckers hurled themselves directly at their targets and at point-blank ranges wreaked havoc over the Western Front.²⁵ Not until the British were able to counter with similar technology the following summer did their fighters achieve parity over the battlefield.²⁶

The gun became a part of the airplane as the best practices from World War I were incorporated into aircraft design. Though the gun itself did not change much during the interwar period, the platforms supporting the guns for the next major war did.²⁷ During the years immediately following WWI, aircraft manufacturers, now able to reflect on aircraft design and fabrication, made drastic changes to their predecessors. An emphasis on metal construction led to replacing wood,

²⁴ Williams, *Flying Guns: World War 1*, 33-38.

²⁵ Metts, *Checking Six is Not Enough*, 5. Lamming, *80 Years of Air to Air Combat*, 17.

²⁶ Lamming, *80 Years of Air to Air Combat*, 18. Bruchiss, *Aircraft Armament*, 16. As a result of confronting the above challenges, neither side controlled the air for the entirety of the war. Though thousands of aircraft had been shot down, the majority had been the result of anti-aircraft fires rather than air-to-air kills. Since the inception of the synchronizing gear in 1915, the only noteworthy change in aerial technology was the presence of more guns on aircraft. More powerful engines allowed airplanes to carry more guns and ammunition. As the gun's presence did promise control of the air, much was left to be desired. Killing in the air was undoubtedly a complex affair and required much more thought and development. Metts, *Checking Six is Not Enough*, 6. Holley, *Ideas and Weapons*, 124-132. Lewis, *Sagittarius Rising*, 181-183. Lawson, *The First Air Campaign*, 69, 220-221.

²⁷ Though there were advocates for pursuit aircraft, airmen possessed by thoughts about bombing led to the falloff of development of guns in fighters. Futrell, *Ideas, Concepts, Doctrine*, 52.

wires, and fabric with metal frames and load-bearing metal “skin.”²⁸ The new semi-monocoque structures had retractable gear and cockpits enclosed by transparent canopies.²⁹ Many components of these aircraft are similar to those found in today’s fighters.³⁰

World War II showcased the gun-fighter. Fighters all around the world sported numerous combinations of internally mounted guns and cannons. The number and types of guns depended on a variety of factors. Perhaps the most important factor involved a gun’s reliability. With changes in aircraft design, aviators were no longer able to service their guns in flight. Machine guns previously attached to the outside of an airplane’s hull were now located inside the wings and/or nose of the aircraft. If a gun jammed in-flight, there was little a pilot could do to fix the weapon. Consequently, the reliability of weapon often took precedence over other factors. The British factored reliability into their calculations when they chose the smaller-caliber, yet proven, US Browning machine gun for their Hurricane and Spitfire fighters.³¹ Though the gun “packed less of a punch,” its reliability ensured pilots were had a viable weapon in most conditions.

Another important factor involved a gun’s caliber.³² Size was important for number of reasons. In light of the hardier metal aircraft

²⁸ Lamming, *80 Years of Air to Air Combat*, 17.

²⁹ Budiansky, *Air Power*, 158. Lamming, *80 Years of Air to Air Combat*, 17.

³⁰ Although the all-metal airplanes were far more robust than earlier aircraft, their performance was limited by a lack of horsepower. Metal aircraft, now designed to carry several internal guns and ample amounts of ammunition, were initially underpowered. The inception of more powerful V-type engines in the 1930s, however, changed the equation. Fighters equipped with these engines were able to carry more and/or heavier guns *while* still being able to achieve faster speeds and higher degrees of maneuverability than earlier fighter equivalents. Consequently, the new aircraft and their new-found “muscle” set the stage for extremely lethal volumes of fire and firepower. Lamming, *80 Years of Air to Air Combat*, 21. Budiansky, *Air Power*, 197-200.

³¹ Mets, *The Evolution of Aircraft Guns*, 91. Heinz J. Nowarra, *The Messerschmitt 109: A Famous German Fighter* (Los Angeles, CA: Aero Publishers, Inc., 1963), 30-32.

³² A gun’s caliber is equivalent to the “diameter of a bore of a gun.” As bullets and other projectiles are tightly fit into a gun’s barrel, caliber also equates to the size of the munitions used. Meriam-Webster’s Collegiate Dictionary, 11th ed., “caliber” (Springfield, MA: Merriam-Webster, Incorporated, 2008), 174.

designs, airplanes were more resilient than they had been in the past. Whereas a rifle bullet fired through a fabric wing and into a flimsy spar led to an aircraft's structural failure in previous times, the same was not true for the modern fighter.³³ In many cases larger caliber rounds were required to cause deadly effects.³⁴ Additionally, big guns typically had longer effective ranges than their smaller counterparts. Germany favored using large caliber guns in its fighters due to their greater ranges.³⁵ German fighters, outfitted with 20 mm cannons, were able to target Allied bomber formations while remaining outside the ranges of the bombers' smaller .303 and .50 caliber machine guns.³⁶

An inadvertent advantage of bigger guns had to do with concentrated fires. Based on their significant recoils, larger guns were positioned in or near the fuselage, where the guns' kickbacks would have less of an effect on the aircraft's structure and performance.³⁷ This placement positioned the barrels along the longitudinal axis of the aircraft. As a result of aligning the guns in this manner, cannon-equipped pilots were able to focus their fires along a single line and, consequently, had to solve only for the lead required to hit a target at range.

Unfortunately, there were also disadvantages to wielding larger caliber guns. Bigger guns were heavier than smaller caliber weapons and required more space aboard the aircraft. Their ammunition likewise weighed more and was larger. Consequently, as the caliber of the guns went up, aviators sacrificed aircraft performance or the number of guns

³³ Mets, *The Evolution of Aircraft Guns*, 90.

³⁴ For example, in the Battle of Britain, "Of the 139 British fighters hit by Bf 109s (German fighter), 63% were shot down and destroyed. Of the 51 hit by return fire from bombers (British), only 25% were shot down." Stephen Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain* (London, UK: Aurum Press, 2000), 196.

³⁵ Nowarra, *The Messerschmitt 109*, 32, 35, 47.

³⁶ Futrell, *Ideas, Concepts, Doctrine*, 78-79.

³⁷ This logic is one of the reasons why the British chose smaller caliber machine guns, which could be positioned further down the wings. Mets, *The Evolution of Aircraft Guns*, 91.

and rounds available. For example, Britain's top fighters and Germany's BF-109 were comparable in performance throughout the war.³⁸

However, while the Hurricane and Spitfire carried 300 rounds of ammunition for each of their eight machine guns, the BF-109 wielded two 20 mm cannons and twin machine guns and carried 60 rounds for each cannon and 1,000 rounds for each of the rifle-caliber guns.³⁹ As the actions servicing the barrels accounted for greater recoil effects and greater energies were required to remove and reload munitions into the barrel's chamber, larger guns also typically meant slower rates of fire. The rates of fire for the BF-109's cannons were half that of the British fighters.⁴⁰

However, a higher number of smaller caliber guns also came with a cost. As numerous guns and their munitions could not all be housed in the small noses of fighter aircraft, designers spread the guns and their bullet caches along the wings. The placement of these guns displaced the bore lines of the weapons and required the guns to be "harmonized" to concentrate the airman's fires. Harmonizing the guns required angling the barrels so the projected munitions would all converge at a desired range.⁴¹ The benefits of coordinating the fires were obvious. The

³⁸ Bungay, *The Most Dangerous Enemy*, 265-266.

³⁹ Emmanuel Gustin and Anthony G. Williams, *Flying Guns: Development of Aircraft Guns, Ammunition and Installations, 1933-1945* (Shrewsbury, UK: Airlife Publishing Ltd., 2003), 98.

⁴⁰ Gustin, *Flying Guns: 1933-1945*, 98. The Browning's (standard British .303 caliber machine gun) rate of fire was 1,350 rounds per minute. The MG 17's (German fighter's 20 mm cannon) was roughly 500 rounds per minute. Gustin, *Flying Guns: 1933-1945*, 17, 98. As indicated above, the volume of firepower a gun could generate at any given time was important. While the Germans, for a time, treated Allied bombers like "ducks in a pond" with their long range cannons, their big guns were far less effective against enemy fighters. The probability of hitting an aircraft in a highly dynamic, three-dimensional air environment was not very high. Accordingly, killing often required firing a high volume of munitions at a target over a short period of time. Such reasoning supported why the British favored having many smaller caliber guns, with higher rates of fire, over possessing fewer larger guns whose rates of fire were much lower. Bungay, *The Most Dangerous Enemy*, 197. Futrell, *Ideas, Concepts, Doctrine*, 78-79.

⁴¹ Early efforts to harmonize a gun were often a result of trial and error. Even though pilots were "asked to open fire at 300 yards, the actual distances varied between 800

problem, however, lay in getting the target to cooperate with this range. Bullets hitting the enemy aircraft closer or further than the point of convergence produced dispersed, shotgun-like effects, and were often unable to bring an adversary down.⁴²

Apart from the guns themselves, considerations regarding ammunition affected the decision matrices of air-minded nations. In many cases, the availability of ammunition drove the selection process. It was far too costly, in time and resources, to modify guns when the required ammunition would be short in coming for the future. Accordingly, guns were often selected based on their commonality with other aircraft and weapons operated by the sea and land forces.⁴³ Aside from availability, different types of bullets affected leaders' decisions. While much of the ammunition used in WWII was similar to that of WWI, there were improvements in ammunition technologies that led to individual rounds being more lethal. Armor-piercing rounds were designed to penetrate reinforced portions of modern airplanes and do more damage to aircraft engines.⁴⁴ Incendiary and high-explosive bullets contained chemical compounds in their hollowed-out centers that, upon contact with an aircraft, would ignite and explode, producing destructive effects above and beyond the kinetic effects of the bullet.⁴⁵ The British, hoping to capitalize on the large volume of fires mentioned above, pursued the more destructive munitions to compensate for their smaller-caliber rounds.⁴⁶ Unfortunately, the bullets carried such a small amount

and 1,200 yards!" Gustin, *Flying Guns, 1933-1945*, 53-54, 94. Bungay, *The Most Dangerous Enemy*, 241.

⁴² Bungay, *The Most Dangerous Enemy*, 241.

⁴³ Gustin, *Flying Guns, 1933-1945*, 10.

⁴⁴ Gustin, *Flying Guns, 1933-1945*, 10.

⁴⁵ Gustin, *Flying Guns, 1933-1945*, 10-11.

⁴⁶ Tests showed the British incendiary ammunitions were twice as effective as their non-explosive counterparts. Gustin, *Flying Guns: 1933-1945*, 37-38. The British attributed some of their fighters' successes against the German aircraft to the development of more powerful ammunition. Bungay, *The Most Dangerous Enemy*, 201.

of explosive material that their efforts may not have produced the results desired.⁴⁷

Though gun-equipped fighters took to the skies all over the world, their presence over Germany was especially important. Not until long-range American P-51s engaged the Luftwaffe fighters were Allied bombers able to accelerate Germany's collapse in the western theater.⁴⁸

Comparable to the British fighters, the P-51 was a highly maneuverable aircraft, possessed numerous machine guns, and carried a significant amount of ammunition.⁴⁹ The US fighter was distinguished, however, by its speed and its ability to out-climb and out-dive Germany's best fighters.⁵⁰ Consequently, once the P-51s were outfitted with expendable drop tanks and were able to escort Allied bombers for the entirety of their routes, the less maneuverable Luftwaffe fighters, relying on large caliber cannons with slow rates of fire and carefully measured supplies of ammunition, were outmatched.⁵¹

The primacy of the internal gun would not be challenged for many years following World War II.⁵² It was not until effective standoff

⁴⁷ Gustin, *Flying Guns: 1933-1945*, 11.

⁴⁸ Futrell, *Ideas, Concepts, Doctrine*, 78-89.

⁴⁹ Gustin, *Flying Guns, 1933-1945*, 157-158. Mets, *The Evolution of Aircraft Guns*, 162-163.

⁵⁰ Mets, *The Evolution of Aircraft Guns*, 163.

⁵¹ Futrell, *Ideas, Concepts, Doctrine*, 78.

⁵² Though the characteristics of the aircraft carrying the weapons would change, many of the above concepts would not. While the Korean War highlighted the speed, maneuverability, and resilience of a new generation of fighters, killing in jet-powered aircraft still depended on the same factors that were accounted for just years before. Airpower leaders balanced reliability, caliber, rates and volumes of fire, and the effects of different types of ammunition. Likewise, aerial combat did not drastically change from the previous war. As pilots were still the best arbiters for when and where to employ their guns, the outcomes of engagements often depended on maneuvering to the rear hemisphere of the intended target and employing guns within the weapon's effective range; the general rule was "the closer the better." If anything, the only notable improvements over WWII involved the superior quality of the pilots. Col Harrison R. Thyng, "Air-to-Air Combat," in *Air Power: The Decisive Force in Korea*, ed. James T. Stewart (New York, NY: D. Van Nostrand Company, Inc., 1957), 32-39. Metts, *Checking Six is Not Enough*, 15-16. Training was accelerated from the outset of the war. Conrad C. Crane, *American Airpower Strategy in Korea, 1950-1953* (Lawrence, KA: University Press of Kansas, 2000), 48.

technologies were incorporated into aircraft design that the primacy of the internal gun was confronted.⁵³ Enamored with countering the high, fast bomber with rockets and missiles and delivering nuclear weapons anywhere in the world, US leaders abandoned the internal gun on multiple occasions during the 1950s and 60s.⁵⁴ Unfortunately, their presumptions rendered F-4 fighter pilots in Vietnam ill-equipped to engage enemy fighters when missiles failed to reach their intended targets.⁵⁵ As the less-than-optimal combat results were revealed, the presence of a gun reemerged; this time in a podded form.⁵⁶

Though the new gun produced adequate results, the temporal character of the weapon did not sit well in the hearts and minds of leaders and operators.⁵⁷ Whereas the internal gun had become part of the aircraft's "DNA," the gun in attached form could be removed at any

⁵³ The fall of the internal gun began with the *promise* of the air-to-air rocket. Though the use of ground-based rockets predated the first cannons, it was not until German scientists explored their potential in the early years of WWII that they were developed for aircraft. The United States aggressively advanced its rocket program after Germany's premier rocket scientist, Wernher Von Braun, surrendered to US ground forces in May of 1945. Army Air Forces Scientific Advisory Group, German Guided Missile Development, 4 October 1945, Call # 203.1, Vol 12, pp. 1, 3, 4, 8, IRIS # 00142361, USAF Collection, AFHRA, Maxwell AFB AL.

⁵⁴ The F-86D, and D, H, J-models of the F-89 were designed without a gun. Additionally, the F-100A, F-102, F-104C, F-105B and early versions of the F-4 did not have guns. Anthony G. Williams and Emmanuel Gustin, *Flying Guns: The Modern Era, Development of Aircraft Guns, Ammunition and Installations since 1945* (Wiltshire, UK: The Crowood Press Ltd., 2004), 99-102. The Navy headed the F-4 program. Their focus on missiles and rockets stemmed from the belief that Soviet bombers would be able to deliver nuclear bombs from altitudes "higher than any fighter could then reach." Glenn E. Bugos, *Engineering the F-4 Phantom II: Parts into Systems* (Annapolis, MD: Naval Institute Press, 1996), 27. Ron Westrum, *Sidewinder: Creative Missile Development at China Lake* (Annapolis, MD: Naval Institute Press, 1999), 25-26.

⁵⁵ Early in Vietnam, missiles were highly ineffective. Lt Col John W. Fahrney, "U.S. Air Force Offensive Counterair Tactics Over North Vietnam, February 1965 to January 1968," Research Report 3599 (Maxwell AFB, AL: Air War College, April 1968), M-U 32983 F1581u c.n. 1, MSFRIC, 32-34. Information is now declassified.

⁵⁶ For a more in-depth description of how the podded form of the gun was developed and pursued, see Maj Seven A. Fino, "All the Missiles Work, Technological Dislocations and Military Innovation: A Case Study in US Air Force Air-to-Air Armament, Post-World War II Through Operation Rolling Thunder" (SAASS thesis, Maxwell AFB, AL: SAASS, June 2010), 105-122.

⁵⁷ Claude G. Morita, "Implication of Modern Air Power in a Limited War," (Interview with General John W. Vogt, Jr., San Francisco, CA: Headquarters, Pacific Air Forces, Office of PACAF History, 29 November 1973): M-U 38245-228 c.n.12, MSFRIC, 25-26.

time. To ensure pilots would not be at the mercy of less reliable technologies, the gun would again be incorporated into future US aircraft designs. However, the heated debates surrounding the internal gun would persist, and the utility of the internal gun is still being debated today. Consequently the costs and benefits surrounding these arguments warrant further analysis.

Equip and Sustain

Incorporating the gun into an aircraft is an expensive proposition. Guns and their ammunition add weight, take up space, and produce unwanted vibrations and emissions; all of which adversely impact a fighter's structural integrity and flight performance. From 1963-65, US aircraft engineers and designers experienced these challenges first-hand as they scurried to integrate an internal gun into a gun-less F-4 fighter. In their efforts to produce the F-4E, they had to remove reconnaissance cameras to fit the gun into the existing airframe, develop shock-absorbent mounts so the "Phantom would not shake apart once the gun began firing at a hundred rounds per second," and create "gas diffusers for the muzzles of the gun to keep gunpowder smoke from asphyxiating the aircraft engines."⁵⁸ The time and resources dedicated to these efforts were substantial.

On the other hand, the costs of incorporating a gun into fighters went down as commonality allowed designers to capitalize on known characteristics and best practices.⁵⁹ The gun that had been assimilated into the F-4E—the six barreled, 20 mm, M61 Vulcan Gatling gun—had already been installed in a number of fighters, to include the F-104, F-

⁵⁸ Bugos, *Engineering the F-4 Phantom II*, 157-159.

⁵⁹ General Dynamics Armament and Technical Products (GDATP) Web site, "General Dynamics Awarded \$8 Million for F/A-18E/F Gun Systems," 5 April 2012, http://www.gdatp.com/media/2012/2012_01_31.asp. GDATP Web site, "General Dynamics Awarded \$24 Million F-35 Lightning II Gun System Contract," 31 January 2012, http://www.gdatp.com/media/2012/2012_01_31.asp.

105, and F-106.⁶⁰ Though heavier than its main competitor, the M-39 20 mm cannon, the M61 generated a rate of fire four times that of its single-barreled counterpart.⁶¹ Additionally, it was more reliable and had a higher expected service life.⁶² Though leaders would still pursue more powerful weapons, the relative benefits of their efforts were less than those of the M61.⁶³ Consequently, based on M61's high level of performance and low maintenance costs, the gun would be incorporated into nearly every fighter following the Vietnam War. The US Air Force's F-111, F-15, F-16, and F-22 and Navy's F-14 and F-18 fighter aircraft all sported the M61.⁶⁴

Changing the gun's caliber, however, is more costly. As stated above, the M61 has been incorporated into the airframes of the majority of contemporary fighters. While integrating the weapon into these

⁶⁰ The M39 (179 lb) is single-barrel gas-operated gun relying on the use of a revolver-type feed mechanism. The M-61's greater weight (251 lb) is the result of having more barrels. Air Force Armament Center, Engineering Flight Test Evaluation of the M39 Gun (Ford Modified), May 1955, Call # K243.805.114, P. 2, IRIS # 1030871, USAF Collection, AFHRA, Maxwell AFB AL. Williams, *Flying Guns: The Modern Era*, 20, 31.

⁶¹ The M39's rate of fire depends on gasses from expended bullets to cycle rounds through the weapon. The M-61's rounds are fed into multiple barrels by an externally powered drive unit. Joseph Berk, *The Gatling Gun: 19th Century Machine Gun to 21st Century Vulcan* (Boulder, CO: Paladin Press, 1991), 59-63.

⁶² The number of barrels and the manner in which the guns were fed contributed to the weapons' reliability and life expectancy. See Maj Dennis C. Carrel, "History of the Aerial Gatling Gun," Research Report 87-0415 (Maxwell AFB, AL: Air Command and Staff College, 1987), 15-16.

⁶³ USAF leaders pursued the promises of a 25/30 mm weapon on multiple occasions without success. Pursuits in the mid-seventies showed the larger weapons produced excessive gasses and yaw moments, which adversely affected the F-15's engine and flight performances. Monte C. Mitchell, *Design Investigation of 30/25mm Gun System in the F-15 Aircraft*, Air Force Armament Laboratory Report AFATL-TR-75-104 (St Louis, MO: McDonnell Aircraft Company, August 1975), M-U 42025 no. 75-104, MSFRIC, 23. Though the M-61 had been integrated into the F-15C and F-16, contracts were being awarded for the development of a new high-performance internal gun for fighter aircraft in 1984. Tactical Weapons Division History, 1 July 1984-31 December 1984, Call # K140.01, IRIS # 01067432, USAF Collection, AFHRA, Maxwell AFB AL. (Secret) Information extracted is unclassified. Based on a number of costs, the new gun would not be fielded. David C. Aronstein, Michael J. Hirschberg, and Albert C. Piccirillo, *Advanced Tactical Fighter to F-22 Raptor: Origins of the 21st Century Air Dominance Fighter* (Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 1998), 110.

⁶⁴ Berk, *The Gatling Gun*, 70.

aircraft designs presented challenges and incurred new costs, there were no research and development (R&D) and acquisition costs associated with the development of a new gun. This changed, however, when the US Air Force selected the 25 mm gun system, the GAU-22/A Gatling gun, for its variant (F-35A) of the Joint Strike Fighter (JSF).⁶⁵ Whereas a modern M61 gun costs approximately \$390,000, the F-35A's new weapon costs \$1 million.⁶⁶

Additionally, the size of the new gun and its bullets affect carriage capacity. While fighters equipped with the M61 have been able to carry several hundred rounds of ammunition, the GAU-22/A's larger caliber restricts the F-35A's carriage to 180 rounds.⁶⁷ Though the gun's bigger shells allow for more explosive effects, providing the pilot with fewer rounds is problematic. In the case of GAU-22/A, fewer rounds equate to fewer available gun attempts.⁶⁸ Additionally, due to the GAU-22A's lower rate of fire, the F-35A pilot fires fewer rounds during each employment of the weapon.⁶⁹ However, while Lockheed remains confident the F-35's larger-caliber munitions and advanced avionics will make up for the lower number of bullets and slower rate of fire, the history of dynamic,

⁶⁵ General Dynamics Armament and Technical Products (GDATP) Web site, "General Dynamics Awarded \$24 Million F-35 Lightning II Gun System Contract." For a description of the GAU-22/A see GDATP Web site, "GAU-22/A," <http://www.gdatp.com/media/factsheets.asp>.

⁶⁶ GDATP Web site, "General Dynamics Awarded \$8 Million for F/A-18E/F Gun Systems," 5 April 2012, http://www.gdatp.com/media/2012/2012_01_31.asp. GDATP Web site, "General Dynamics Awarded \$24 Million F-35 Lightning II Gun System Contract."

⁶⁷ The F-14 carried 767 rounds. The F-15C, F-15E, F-16, F-18, and F-22 carry 940, 500, 512, 570, and 480 rounds, respectively. Williams, *Flying Guns: The Modern Era*, 111-112. Col Charles Moore, "The Need for a Permanent Gun System on the F-35 Joint Strike Fighter" (USAF Fellows Paper, The Weatherhead Center for International Affairs, Harvard University, April 2007), 21.

⁶⁸ The M-61 is designed to fire at rates of 4,000 and 6,000 rounds per minute (rpm). Berk, *The Gatling Gun*, 60. The higher setting (100 rounds per minute) is most often used against maneuvering targets. Maj James C. McFarland (former Chief of instructors for F-15C Division, USAF Weapons School), interview by author, 1 May 2012.

⁶⁹ The GAU-22/A's published rate of fire is 3,300 rpm. This equates to 55 rounds per second. GDATP Web site, "GAU-22/A."

aerial combat, which highlights the importance of available ammunition and high rates of fire, suggests otherwise.⁷⁰

In some cases, the gun has been integrated into aircraft design based on providing intangible benefits rather than analysis of more tangible costs. While the tradeoffs of replacing a gun with something else have often been clear, there have been times when they were not. For example, it was clear that integrating a gun into the F-4 and F-101 meant removing reconnaissance equipment in the fighters' extended noses.⁷¹ However, in the F-22's case, where adding the gun did not involve foregoing mission-essential equipment and did not adversely affect the aircraft's performance, the cost-benefit analysis was more murky. In 1995, Mr. Jon T. Graves, then Deputy Director of F-22 System Program Office, commented on the decision to put the M61 in the F-22:

At the state of design of the aircraft right now, you wouldn't be able to do much with the space. Other than maybe put some fuel in it [removing the gun would have saved 850 pounds], or something like that. So rather than go through and scrap work that had already been done, or go back and redesign that very significant portion of the airplane packaging, it was determined that we will leave the gun in. Now there was a very strong vote from the fighter pilot community to not take the gun out...And the way we looked at it was, rather than say "could we replace this with this," was to say "what happens if you take this out?" And then what happens if you put this in? What's the relationship? What does it mean to the fighter pilot? We did some more simulations to determine what the kill probabilities were and things of that sort. The gun is not a significant "add-on," but in the eyes of the fighter pilot, whose life is on the line, when all those missiles are dead and gone, and they're not all with me anymore, he still wants something to go home with. And if he gets jumped, he'd still like to have something on the

⁷⁰ Moore, "The Need for a Permanent Gun," 22.

⁷¹ Bugos, *Engineering the F-4 Phantom II*, 157. Williams, *Flying Guns: The Modern Era*, 100.

trigger. So from a non-objective point of view, I can understand why they feel like the 800 pounds are worth it.⁷²

From Mr. Grave's comments it is evident that, although creative engineers and designers probably could have found ways to trade the gun's space and weight for more fuel, oxygen, avionics, and possibly weapons, incorporating the gun into the F-22 was a cost-effective measure and psychologically prudent.⁷³

⁷² Oral History Interview of Mr. Jon T. Graves by Dr. Paul C. Ferguson, 6 January 1995, typed transcript, pp. 5-7, Call # K239.0512-2196, IRIS # 01129470, USAF Collection, AFHRA, Maxwell AFB AL. Mr. Graves' argument is based on removing the gun after it had been incorporated into the initial design. Had the gun not been a requirement to begin with, the gun's space and weight could have been accounted for differently. Unfortunately US designs have not tested this hypothesis. The USN (nor USMC) variant of the JSF, the F-35C, does not have an internal gun and its combat radius is 25-30 percent greater than the F-35A. However, as an aircraft's combat radius does not necessarily translate to better flight performance, it is difficult to determine if the lack of a gun is an advantage. For example, the F-35C is heavier than the USAF variant, due to its reinforced structure for carrier operations, and it is likely the fighter is far less maneuverable. Anthony Murch and Christopher Bolkcom, *F-35 Lightning II Joint Strike Fighter (JSF) Program: Background, Status, and Issues*, Congressional Research Service Report (Washington, D.C.: Congressional Research Service, 25 October 2007), 4. Maj Gen Charles R. Davis, "F-35 Program Overview," (Aviation Week Brief, 13 February 3008), 14, http://www.jsf.mil/downloads/down_documentation.htm. Colonel Bob Lyons, "Joint Strike Fighter" (Briefing, Arlington, VA: Joint Strike Fighter Program Office, 13 June 2001), 8. Finally, with regard to the weight of the gun and the F-22, the fighter's high thrust-to-weight ratio allowed for its carriage. Earlier, in the F-15C, where engine technology was not as advanced, weight mattered more. For example, decision makers elected to keep the gun despite its impact on flight performance. They even elected to change the aircraft's performance requirements to account for more weight. Maj Robert F. Debusk III, "Acquisition of the F-15, 1969-1974," Research Report 85-0655 (Maxwell AFB, AL: Air Command and Staff College, 1985), pp. 46-47, Call # K239.043-73, IRIS # 01072099, USAF Collection, AFHRA, Maxwell AFB AL. (Secret) Information extracted is unclassified.

⁷³ The M61 occupies roughly 7.8 cubic feet of space and weighs 251 lb, not including the volumes and weights of the feed and handling system, storage container for the bullets, and the bullets, themselves. The subsystems' volumes and weights vary, depending on the number of rounds carried and advancements in technology. A reasonable assumption is 17 cubic feet for the bullet drum and 600 lb for the weight of the feed system, drum, and bullets (average of fourth generation gun systems). Berk, *The Gatling Gun*, 60. Williams, *Flying Guns: The Modern Era*, 111-112. The AIM-120, the USAF's long medium-long range missile, takes up 34 cubic feet (based on radii of fins and missile body) and weighs 356 lb. Raytheon Company, *AMRAAM: Advanced Medium-Range Air-to-Air Missile* (Tucson, AZ: Raytheon Company, 2007-2008), 2. The AIM-9X, the US' short-range missile, requires 65 cubic feet and weighs 118 lb. Raytheon Company, *AIM-9X Sidewinder Fifth Generation High Off-boresight, Thrust-Vectored Air-to-Air Missile* (Tucson, AZ: Raytheon Company, 2003-2008), 2. Note, the gun and missiles require more oblong volumes (rather than wider and taller) for carrying the weapons.

Whereas incorporating a gun into an aircraft is a sunk cost and an advantage, the expenses related to the avionics supporting the contemporary weapons are not. Though the development of various sighting technologies has paralleled the evolution of the gun, the costs associated with earlier efforts do not compare to those required for computing and relaying electronic information in modern fighters, where there are numerous electronic linkages between the gun, radar, central computer, and a host of “pilot-friendly” displays.⁷⁴ Unfortunately, the computer code supporting modern connections has to be updated or changed every time a new variable is introduced into the calculations.⁷⁵ For example, the advent of a faster bullet requires writing new code so the computer will display the correct firing solution in the pilot’s heads-up display; in this case, assuming an aerial engagement is treated as a constant, the new code should demand less lead fire. With continuous and more complex advancements in technology, expending the time and resources to update and/or write new code becomes a costly affair.⁷⁶

Another recurring cost involves ammunition. While the gun has not significantly changed over time, the projectiles leaving its barrels have. Since the introduction of explosive munitions, scientists and engineers have continued to pursue new ways for achieving more effects from the same caliber round. The research and development, testing,

⁷⁴ Computer-based sighting technologies were first used in F-86 Sabres over Korea. See Kenneth P. Werrell, *Sabres Over Mig Alley: The F-86 and the Battle for Air Superiority in Korea* (Annapolis, MD: Naval Institute Press, 2005), 26-33. However, the Sabre’s technologies were rudimentary in comparison to what sighting technologies are capable of today, where many more factors are incorporated into the computer’s calculations. Though fourth-generation fighters (e.g. F-15s, F-16s, and F-18s) have had to deal with the problems associated with integrated systems, fifth generation fighters are worse off. For an example of the F-22’s complexity, see Defense Industry Daily Web site, “The F-22 Raptor: Program & Events; Raptor, Redux: Upgrading the Fleet,” 29 March 2012, <http://www.defenseindustrydaily.com/f22-raptor-procurement-events-updated-02908/>. For the F-35’s, see Davis, “F-35 Program Overview,” 17-18.

⁷⁵ Maj Jason Camilletti (former F-22 Squadron Weapons Officer and Director of Operations), multiple interviews by author, March-April 2012.

⁷⁶ The F-22’s software updates are often slow to be implemented as a result of the costs. Defense Industry Daily Web site, “The F-22 Raptor.”

and fielding associated with new munitions have incurred additional and increased costs. Changing the caliber of the gun and ammunition further compounds the costs. For example, a one-second burst of 25 mm rounds from the GAU-22/A costs roughly \$2,000 while the same action costs \$1,250, using the 20-mm M61.⁷⁷

With regards to paying for training expenses, the costs associated with the gun are a mixed bag. Training is conducted through live or non-live fires. Live fires may be as simple as shooting the gun in the air, to ensure the gun works properly, or as complex as involving several aircraft taking turns firing their loads of ammunition at a target being towed behind another aircraft. Simply shooting the gun equates to the costs of the ammunition. For example, eight F-15Cs firing 940 rounds of 20 mm PGU-28A/B costs around \$90,000.⁷⁸ Paying for a tow aircraft and a target costs an additional \$6,250 or \$11,700, depending on the character of the aircraft.⁷⁹

⁷⁷ Gun employment is not an “all or nothing” event. Assuming a pilot can achieve desired effects with a one-second burst and the effects are equivalent to those of a missile, the F-15C’s available number of rounds is equivalent to nine missiles and the F-35’s equal to three. See footnotes 67, 68, and 69 of this chapter. Additionally, if the cost of a 20 mm round is roughly \$12 and a 25 mm round costs \$36, each one-second burst from an F-15C (100 rounds) and F-35 (55 rounds) would cost roughly \$1,250 and \$1,980, respectively. The contract in 2003 for 861,674 rounds of PGU-28A/B (common round used by M61-equipped fighters) cost \$10,181,358. Office of the Assistant Secretary of Defense, *Contract*, Public Affairs Release 342-03 (Washington, D.C.: Department of Defense, 19 May 2003), <http://www.defense.gov/contracts/contract.aspx?contractid=2156>. The contract in 2010 for 258,843, 25 mm rounds cost \$9,336,321. Office of the Assistant Secretary of Defense, *Contract*, Public Affairs Release 577-10 (Washington, D.C.: Department of Defense, 6 July 2010), <http://www.defense.gov/contracts/contract.aspx?contractid=4316>. Furthermore, the cost of gun burst’s effects is less than that of modern day missiles. An AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) costs \$1.2 million. The shorter range AIM-9X Sidewinder missile costs \$750,000. Lt Col Jason D. Lollar (USAF Air Combat Command, ACC/A8ZA), interview by author, 26 April 2012.

⁷⁸ Math based on previous discussions. See footnotes 67, 68, and 77 of this chapter.

⁷⁹ A target “banner” costs \$6,250. There are two options for towing a target, the USAF QF-4 and a civilian Lear jet. The QF-4, as part of the USAF contracted flying hour program, incurs no additional costs. The Lear costs roughly \$5,700 for one banner mission. Michael J. King (USAF Air Combat Command, ACC/A3TO), interview by author, 26 April 2012. Andrew D. Spires (USAF Air Combat Command, ACC/A3TW), interview by author, 26 April 2012.

While these costs seem considerable, they pale in comparison to getting live-fire experience using other weapons. Whereas the gun can be employed in many of the airspaces used by USAF and USN fighters, the majority of fighters have to travel to off-site locations to fire missiles. For example, based on range limitations and evaluation requirements, USAF fighter units deploy to Tyndall AFB, FL to conduct live fires using their long range armaments.⁸⁰ The costs related to sending aircraft, pilots, maintainers, and other support resources to the USAF's air-to-air missile range are significant. The temporary duty (TDY) expenses for sending 12 jets and 130-145 personnel, alone, cost around \$375,000.⁸¹ Adding in the numerous expenses associated with maintaining, employing, tracking, and analyzing the million-dollar missiles' data, the total actual costs for firing missiles is much higher.⁸² In addition to travel expenses, the frequency with which USAF fighters are able to go to Tyndall AFB imposes a cost.⁸³ Under COMACC Plan 85, air-to-air designated aircraft *should expect* to go to WSEP once a year.⁸⁴ While available funding often supports this expectation, the promise of COMACC Plan 85 does not

⁸⁰ USAF Fighters operate under the guidance of Commander Air Combat Command (COMACC) Plan 85, which requires aircraft to fire missiles in support of the Weapons System Evaluation Program (WSEP). Operations supporting operational missile test and evaluation are currently conducted from Tyndall AFB, FL. See COMACC Plan 85, *Combat Archer, Air-to-Air Weapon System Evaluation Program* (Headquarters, USAF Air Combat Command, Langley AFB, VA, 20 August 2007).

⁸¹ Spires, interview by author, 26 April 2012.

⁸² Spires, interview by author, 26 April 2012.

⁸³ Based on TDY expenses and the logistics of moving short-range fighters over the oceans, USAF units overseas tend to frequent Tyndall AFB less than their US-based counterparts. F-15C and F-22 Squadron and Wing Weapons Officers from Combat Air Forces, Air National Guard, and Reserve organizations, interviews by author, 11-14 April 2012. USN fighters are able to fire missiles while at sea by establishing restricted flying areas around or near their carrier. However, as there are fewer resources for collecting and analyzing missile data, the focus of these types of operations is more on firing the weapons than conducting tests and evaluations. Maj Matthew Neuman (Assistant Operations Officer, Carrier Air Wing 3), interview by author, 24 May 2012. Author's personal experience with USN operations.

⁸⁴ COMACC Plan 85, 6.

compare to the potential for getting live-fire experience at home, where individual squadrons are better able to dictate their schedule.⁸⁵

Unlike live-fire training, where the cheapest training still incurs costs, non-live-fire training incurs no noteworthy costs. As modern guns are “de-armed” on the ground prior to taking flight, no bullets are expended when the pilot pulls a trigger or hits a button to employ the gun for training purposes.⁸⁶ The sighting logic does not change and the pilot sees the same information as he would if the gun were armed.⁸⁷ Perhaps the only costs of a de-armed gun involve not being able to hear the gun’s noise, feel its vibrations, and smell the gasses from expended bullets.

Peacetime Employment

The gun provides a variety of peacetime benefits at very low cost. One of the more obvious benefits involves training opportunities. There are countless scenarios in which the lack of fuel, time, and/or aircraft availability does not support more complex training. For example, at the end of a training scenario involving a large number of aircraft, there may be only two or three left with enough fuel for extra maneuvering.⁸⁸ Additionally, the scheduled airspace period may prohibit taking the time to set up another longer-range scenario.⁸⁹ Finally, due to maintenance issues, there may have been only two air-worthy jets airborne to begin with.⁹⁰ In the above examples, employing simulated missiles and bullets in “dog-fights,” commonly known as basic fighter maneuvers (BFM),

⁸⁵ The budget for ACC fighters is roughly \$2.5 million a year. Spires, interview by author, 26 April 2012. Not including the USAF Weapons School squadrons (who go to WSEP twice of year for syllabus requirements), there are two F-15E, seven F-16, three F-22, and one-blended (422nd Test and Evaluation Squadron) squadrons that fall under ACC.

⁸⁶ F-15C, F-15E, and F-22 pilots, interviews by author, March-April 2012.

⁸⁷ F-15C, F-15E, and F-22 pilots, interviews by author, March-April 2012.

⁸⁸ F-15C and F-22 Squadron and Wing Weapons Officers from Combat Air Forces, Air National Guard, and Reserve organizations, interviews by author, 11-14 April 2012.

⁸⁹ Weapons Officers, interviews by author, 11-14 April 2012.

⁹⁰ Weapons Officers, interviews by author, 11-14 April 2012.

provides more opportunities for training.⁹¹ Setting up a BFM engagement requires minimal fuel and time. Executing close-quarters maneuvers burns fuel faster as a result of the high power settings used and, consequently, takes less time. Lastly, only two fighters are needed for a fight.

Though missiles are fired throughout the entirety of BFM engagement, focusing on the *gun* in BFM is important for a variety of reasons. For one, training to the gun enhances survival. At base, maneuvering for a gun kill often requires flying to the space aft of the enemy aircraft. As this position is offensive in character, it enhances the attacker's chances for survival should his missiles fail. As will be discussed later in this chapter, the thought of a missile failing should weigh heavily into a pilot's calculus.

Focusing on the gun also leads to better missile employment. Flying to an optimal position for gun employment requires very precise airmanship, as gunning an aware adversary is an exceptionally difficult task.⁹² Serendipitously, the airmanship required to achieve a valid gun kill is desirable for missile employment. Though the modern fighter is likely to be in a "missile" weapon employment zone (WEZ) from the outset of an engagement, merely being in a position to fire does equate to a high probability for a kill (commonly referred to as probability-of-kill or Pk); since the likelihood of a missile hitting and killing a target varies with the

⁹¹ For a detailed description of what BFM entails, see Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.F-15, 4 November 2010, 22-73.
<https://wwwmil.nellis.af.mil/units/561jts/>. (Unclassified//FOUO)

⁹² As evident by the historical analysis at the beginning of this chapter, gunning an aware adversary is an exceptionally difficult task. BFM and gun employment in today's environment are no different. Forward hemisphere shots are extremely fleeting and stern hemisphere shots require maneuvering to a very specific region behind the adversary. Unfortunately, as in the past, most adversaries will maneuver aggressively to deny the attacker from being within range and establishing enough lead fire for a gun shot. BFM, for these reasons, entails precision maneuvering to achieve a position of advantage. See Capt Robert D. Davis, "Applying the Control Zone in Offensive Basic Fighter Maneuvers" (USAF Weapons School Paper, Nellis AFB, NV: USAF Weapons School, 12 June 2004).

attacking aircraft's position.⁹³ Firing from *optimal* positions requires very precise maneuvering and acute visual assessments in a highly dynamic and g-force intensive environment.⁹⁴ Consequently, as the highest levels of assessments and maneuvering are required to achieve a gun-kill in BFM, training to the gun provides a solid foundation for missile employment.

Furthermore, the skills obtained from maneuvering in relation to a gun WEZ enhance *visual* cross-checks in other areas of flying. BFM-related skills are invaluable for maintaining visual situational awareness in relation to flying formation, remaining clear of dangerous weather, and avoiding contact with terrain. The skills are especially important during beyond visual range (BVR) engagements, when pilots' eyes are in the cockpit processing a substantial amount of electronic information.⁹⁵

On the ground, BFM makes it easier to learn the basics of a mission debrief. In comparison to the large-scale, simulated wars that

⁹³ Lt Col Christian D. Kane (83rd Fighter Weapons Squadron's Director of Operations [in charge of facilitating WSEP's Combat Archer]), interview by author, 2 May 2012. See also United States General Accounting Office, AIM-9X Acquisition: Missile Risk Reduction Underway but System Production Plans Need to be Reexamined, Report to the Committee on National Security, House of Representatives (Washington, D.C.: United States General Accounting Office, April 1998), 24-25. The weapons engagement zone is the volume of space defined by the capabilities of a weapon. The size of a WEZ depends on a variety of factors, to include the flight parameters of the targeted and attacking aircraft and environmental conditions. Employing a weapon while in the WEZ does not guarantee lethal effects but rather significantly increases the chances of the weapon and/or its effects finding and hitting the target. AFTTP 3-3.F-15, 4 November 2010, 22-73. Author Robert K. Wilcox describes it well: "For instance, in a dogfight at 5000 feet, you had to be within one-half mile to two miles for a good tailshot with the Sparrow. You also had to be within a certain "lethal cone" projected from the target's tail. The cone was a fluctuating, irregularly shaped pattern emanating from the bogey's front, back or side. It was a mile to three miles if you were abeam of him and was two to four miles for a good head shot. Your missile had to be within the parameters of the invisible cone in order to work properly. In some cases, the latitude between minimum and maximum ranges was only 500 feet." Robert K. Wilcox, *Scream of Eagles: The Creation of Top Gun and the U.S. Air Victory in Vietnam* (New York, NY: John Wiley & Sons, Inc., 1990), 108.

⁹⁴ Maj Jack R. Arthaud and Maj James C. McFarland (both former Chiefs of instructors for F-15C Division, USAF Weapons School), multiple interviews by author, March-April 2012.

⁹⁵ Again, see Davis, "F-35 Program Overview," 17-18. Weapons Officers, interviews by author, 11-14 April 2012.

take place over and through the valleys of Nevada, gun employment encompasses a limited number of variables.⁹⁶ Consequently, it is less difficult to engage the “perception, decision, execution” framework used by most pilots for facilitating instruction in the debrief.⁹⁷ The skills a pilot hones in the BFM debrief are readily transferable to more complex missions.⁹⁸ The same argument cannot be made in reverse.

Aside from the benefits associated with BFM, the gun produces several psychological benefits. First, being around live ammunition reminds pilots of the realities of warfare. Whereas regulations prohibit USAF pilots from conducting aerial training with live missiles aboard the aircraft, the same is not true for ammunition. Consequently, as pilots perform their preflight inspections of the aircraft, physically ensure a potentially live gun is de-armed prior to flight, and execute inflight checks related to the weapon, they are keenly aware of the dangers of their craft. Their heightened sensitivities help reduce “video game” mentalities resulting from not having employed a live weapon or having been deployed for the purpose of combat in some time.⁹⁹

More importantly, live-fire training develops confidence. While nearly every fighter pilot acknowledges that there are numerous reasons why a missile might not find its target, the same cannot be said for the gun. Whereas missiles fired over the Gulf of Mexico might fail due to radars falling off-line, batteries quitting, instruments freezing up, and a host of other reasons, pilots quickly learn through live-fires training that *execution* is often the reason why bullets do not hit the target.¹⁰⁰

⁹⁶ Capt Robert L. Brown, “Methodology of the Debrief” (USAF Weapons School Paper, Nellis AFB, NV: USAF Weapons School, 10 June 2006). Capt Ethan M. Waitte, “Standardizing F-22 Debrief” (USAF Weapons School Paper, Nellis AFB, NV: USAF Weapons School, 13 June 2009).

⁹⁷ Weapons Officers, interviews by author, 11-14 April 2012.

⁹⁸ Brown, “Methodology of the Debrief.”

⁹⁹ Weapons Officers, interviews by author, 11-14 April 2012.

¹⁰⁰ Weapons Officers, interview by author, 11-14 April 2012. Over the last three years the gun has an extremely high reliability rate. In 1,052 gun attempts, the F-15C’s system worked 97 percent of the time. The F-15E’s, F-16’s, F-18’s, and F-22’s gun

Consequently, as their proficiency with the weapon grows, so does their confidence, both in the weapon and in themselves.¹⁰¹

This confidence leads to desirable second and third-order effects. As gun employment is driven by the individual, it often leads to a competitive environment in the squadron. Spurred on by competition, pilots aggressively pursue the title of “Top Gun” and diligently work to rack up gun kills in training.¹⁰² According to observations of several combat-mission-ready weapons officers, these behaviors promote a desired aggressiveness that spills over into other areas of aerial employment.¹⁰³ Additionally, they contend it significantly bolsters the morale of the squadron.¹⁰⁴

The only notable cost of the gun in peacetime involves the amount of training associated with employing the weapon. As with the bayonet, time devoted to the gun competes with opportunities for other types of training. Based on training syllabi and annual flying requirements, USAF F-22 and F-15C squadrons currently dedicate between 10 and 20 percent of their training to BFM and gun employment.¹⁰⁵ As these aircraft are primarily responsible for the air-to-air mission in major combat operations, there are few to no complaints with regards to the amount of time dedicated to close-quarters maneuvering. The same may not be the case for pilots responsible for both air-to-air and air-to-ground

systems worked 98 (286 attempts), 97 (384 attempts), 99 (231 attempts), and 95 (308 attempts) percent of the time, respectfully. Maj Matthew Minkley, Program Manager, 83rd FWS, to the author, email, 3 May 2012.

¹⁰¹ Part of the confidence also comes from knowing that the gun has *recently* been tested via live fires. As modern fighters only carry one gun per aircraft, guns are tested more often than their missile-related components. For example, and F-15C deployed to Tyndall does not fire a missile off of each of its eight stations during the deployment. Consequently, if there is a bad station, there may be several years and deployments before the problem area is discovered and fixed. Weapons Officers, interviews by author, 11-14 April 2012.

¹⁰² Weapons Officers, interviews by author, 11-14 April 2012.

¹⁰³ Weapons Officers, interviews by author, 11-14 April 2012.

¹⁰⁴ Weapons Officers, interviews by author, 11-14 April 2012.

¹⁰⁵ Weapons Officers, interviews by author, 11-14 April 2012.

roles, where the demands on a squadron's training program are much higher.¹⁰⁶

Wartime Employment

The gun has a variety of wartime benefits and costs. Perhaps the most important benefit is the psychological comfort the gun provides in light of a highly uncertain operational environment. Fundamentally, the gun bridges the gap between the operator and missiles. The gun, like the ram and bayonet, provides an enduring option for attack and defense. Short of suicidally ramming his aircraft into a target, the pilot has nothing to do once he has expended all of his missiles.¹⁰⁷ Suicide provides little in the way of psychological comfort and is generally bad for unit morale.

As with the bayonet, the ambiguous character of the aerial combat has nurtured the need for a highly reliable weapon. There are several driving factors contributing the uncertainties surrounding combat in the air. The likelihood of fighters entering the within visual range (WVR) environment and a merge (a close pass between two aircraft) taking place is a driving factor. Resonating in the mind of every fighter pilot is a *history* of reasons for opposing fighters finding themselves in close-quarters situations. For example, political constraints have driven merges. During the Vietnam conflict, politically-based rules of engagement prohibited pilots from taking advantage of their long-range

¹⁰⁶ However, based on comments from a former F-15E Squadron Weapons Officer, dual-role fighter pilots view BFM in the same manner as their air-to-air counterparts. During the interview, he commented, "The skills learned during BFM and gun employment underpin all other training." He further highlighted that during his tenure in several squadrons, BFM accounted for roughly 10-15 percent of the all training requirements. Lt Col Benjamin Bishsop (former F-15E Squadron Weapons Officer), interview by author, 29 April 2012.

¹⁰⁷ Pilots have attempted to ram their targets despite low odds for survival. Lt. Petr Nikolaevich Nesterov, of the Imperial Russian Army, rammed his unarmed monoplane into an Austrian aircraft in an attempt to stop his adversary from flying overhead his homeland. As could be expected, Lt. Nesterov did not survive the collision. Lamming, *80 Years of Air to Air Combat*, 13.

missiles.¹⁰⁸ Instead of killing their targets at range, they had to visually identify their adversaries and sometimes get approval prior to firing their more capable weapons. Aside from political factors, the presence of too many adversaries has caused aircraft to merge. In the Yom Kippur War, it was not possible for the Israeli Air Force to put enough aircraft and missiles into the air to account for the more numerous Arab fighters.¹⁰⁹ Another factor involved the adversary's abilities to deny situational awareness (SA) and capitalize on surprise attacks. With knowledge of US employment limitations and equipment shortfalls, enemy MIGs regularly "jumped" US aircraft early in the Vietnam conflict.¹¹⁰

Historical missile employment data is in line with the above assessments. According to a 2008 RAND report, only 24 out of the world's 588 recorded air-to-air kills have occurred beyond visual range (BVR).¹¹¹ Though the percentage of BVR kills has gone up since the advent of the Advanced Medium Range Air-to-Air Missile (AMRAAM), the percentage remains dismally low. Only 20 of the US's 61 recorded kills since 1991 have taken place outside of visual range.¹¹² This data points to the likelihood of combat taking place in the close-quarter's environment.

¹⁰⁸ Two reasons contributed to the restricted character of the rules of engagement. American systems technologies responsible for BVR identification was still in their infancy. Additionally, US leaders did not want to chance shooting down an enemy fighter originating from China. Bugos, *Engineering the F-4*, 157.

¹⁰⁹ Shmuel L. Gordon, "Air Superiority in the Israel-Arab Wars," in *A History of Air Warfare*, ed. John Andreas Olsen (Washington, D.C.: Potomac Books, Inc., 2010), 141-148.

¹¹⁰ 433rd Tactical Fighter Squadron History: 1 Jan 68 – 31 Mar 68, in 8th Tactical Fighter Wing History: Jan – Mar 1968, Call # K-WG-8-HI, Vol I, pp. 32-36, IRIS # 00447613, USAF Collection, AFHRA, Maxwell AFB AL. Information is now declassified. For a wealth of combat stories, see R. Frank Futrell, William H. Greenhalgh, Carl Grubb, Gerald E. Hasselwander, Robert F. Jakob, and Charles A. Ravenstein, *Aces and Aerial Victories: The United States Air Force in Southeast Asia, 1965-1973*, ed. James N. Eastman, Jr., Walter Hanak, and Lawrence J. Paszek (Washington, D.C.: The Albert F. Simpson Historical Research Center and Office of Air Force History, 1976).

¹¹¹ John Stillion and Scott Perdue, *Air Combat Past, Present and Future*, RAND Report Project Air Force (Santa Monica: CA, RAND, August 2008), 21. (Unclassified//FOUO//Sensitive)

¹¹² Stillion, *Air Combat*, 23.

Current realistic training results further support the likelihood of merges taking place. USAF F-15Cs and F-22s, the aircraft primarily responsible for air-to-air employment, train exclusively to the most dangerous threats and scenarios. According to a number of current F-15C and F-22 weapons officers, merges happen roughly half of the time while executing short-range intercepts and a quarter of the time in longer range engagements.¹¹³ Three of the factors driving the merge percentages are the number of adversaries encountered, the tactics they employ, and the degraded electronic environment they are able to generate.¹¹⁴ In large-force training scenarios, to include those executed at Red Flag, the numbers are not far different.¹¹⁵

Up to this point, nothing has been said about the quality of missiles. Perhaps the most significant factor in the pilot's calculus is a lack of faith in standoff technologies. Though many pilots deployed to Tyndall AFB experience the exuberance associated with seeing their live missiles finding their marks, they also acknowledge the numerous vulnerabilities associated with the thousands of calculations that take place between the time the pilot hits the pickle button and the time a missile impacts its target.¹¹⁶ Given that their aircraft carry a small

¹¹³ A short-range intercept is a BVR engagement in which the range from the adversary's forces makes it more difficult (with time limitations) to determine the number and positions of enemy aircraft and employ longer-range effects. Weapons Officers, interviews by author, 11-14 April 2012.

¹¹⁴ Weapons Officers, interviews by author, 11-14 April 2012.

¹¹⁵ Weapons Officers, interviews by author, 11-14 April 2012.

¹¹⁶ Kane, interview by author, 2 May 2012. Current opinions are not far different from those in the years after Vietnam. C.R. Anderegg, *Sierra Hotel: Flying Air Force Fighters in the Decade After Vietnam* (Washington, D.C.: Air Force History and Museums Program, 2001), 143-146. Pilots deployed in support of WSEP receive intensive academics on the weapons they employ, are closely monitored during employment, and engage in thorough debriefs with regard to their aircraft and weapon results. 2nd Lt Will Powell, "Operational Raptors Fire First Missiles in Raptor," USAF Air Education and Training Command News (Tyndall AFB, FL: 325th Fighter Wing Public Affairs, 21 February 2006), <http://www.aetc.af.mil/news/story.asp?id=123025811>.

number of munitions, they continue to demand more reliable technologies.¹¹⁷

History supports the above uncertainties. Going into Vietnam, the estimated Pk for the F-4's BVR missile, the AIM-7 Sparrow, was 70 percent.¹¹⁸ However, in actuality, missiles destroyed their targets only 8 percent of the time.¹¹⁹ Though marginally better, the AIM-7's Pk in the Gulf War was 25 percent.¹²⁰ With regard to the AMRAAM (AIM-120), only 59 percent (10 of 17) of the missiles that have been fired in combat have killed their targets.¹²¹ At first glance, the percentage appears acceptable. However, digging deeper, the data related to the US's ten AIM-120 kills is not so promising.¹²² With regard to the kills:

- 4 occurred within visual range
- 13 missiles were fired to achieve the 6 BVR kills¹²³
- 2 kills involved fleeing and non-maneuvering adversaries
- 1 kill was against a light attack/reconnaissance aircraft
- 1 kill was against an unaware, friendly helicopter
- 2 kills were against enemy fighters with inoperative radars
- No victim employed electronic counter-measures (ECM)
- No victim had comparable BVR weapons
- All engagements involved parity or US numerical superiority

¹¹⁷ The F-16 can carry up to six air-to-air missiles. The F-15, F-18, and F-22 can carry up to eight. Author's personal experience. National Museum of the Air Force Web site, "Fighter Aircraft,"

<http://www.nationalmuseum.af.mil/research/aircraft/fighter/index.asp>.

¹¹⁸ Stillion, *Air Combat*, 20.

¹¹⁹ Stillion, *Air Combat*, 20.

¹²⁰ Gulf War Air Power Survey, *A Statistical Compendium and Chronology*, vol. 5 (Washington, D.C., 1993), 91.

¹²¹ Stillion, *Air Combat*, 20. USAF fighters no longer employ the AIM-7. USN fighters employ both the AIM-7 and AIM-120.

¹²² Stillion, *Air Combat*, 25.

¹²³ The report did not indicate whether or not the number of missiles fired was due to employment procedures (launch multiple missiles), missile failures, or weapons missing their targets. Most often, pilots employ a "shoot-assess-shoot" philosophy to preserve armament. Arthaud and McFarland, multiple interviews by author, March-April 2012.

As none of the above data supports engagements against a robust air-to-air threat, it is easy to see why pilots are cautious when it comes to putting faith in BVR missiles.

Short-range missiles, on the other hand, have a mixed history. During the close-in fighting in Vietnam, heat-seeking AIM-9 Sidewinder missiles destroyed their targets 15 percent of the time.¹²⁴ Later, after modifications had been made to the missile, 19 of the 26 AIM-9s fired during the Falklands conflict in 1982 resulted in kills.¹²⁵ Regrettably, as many nations developed effective counters for new AIM-9's capabilities, the missile's Pk dropped back to 23 percent in Desert Storm.¹²⁶ Based on the above trends, it is likely the US's newest missile, the AIM-9X, will turn the tides again.¹²⁷ However, the fact that enemies have the capacity to adapt and overcome generates a degree of uncertainty.

While much of the above data has to do with missiles failing, there are other variables affecting the performance of missiles. Poor missile performance is often the result of the enemy's capabilities and actions. As already alluded to, electronic and infrared countermeasures (ECM or ICM) affect missile performance. Enemy ECM prevents radars from supplying correct data to missiles and degrades pilots' situational awareness..¹²⁸ Short-range missiles track signatures similar to the

¹²⁴ Stillion, *Air Combat*, 26.

¹²⁵ Stillion, *Air Combat*, 26.

¹²⁶ Stillion, *Air Combat*, 26. A comparison between Gulf War Survey data and the list of US kills paints a different picture. Out of the 86 missiles expended during the war, only 11 resulted in kills (roughly a 13 percent Pk). Gulf War Air Power Survey, *A Statistical Compendium and Chronology*, 553, 653-654. Craig Brown, *Debrief: A Complete History of U.S. Aerial Engagements 1981 to the Present* (Atglen, PA: Schiffer Publishing Ltd., 2007), 186. Roy A. Grossnick, "List of Navy and Marine Corps Shoot Downs Since 1950," in *United States Naval Aviation, 1910-1995*, Appendix 33 (Washington, D.C: Naval Historical Center, Department of Navy), 770-771, <http://www.history.navy.mil/branches/usna1910.htm> (Appendix 33).

¹²⁷ For a description of the missile's latest capabilities, see Raytheon Web site, "Aim-9X," <http://www.raytheon.com/capabilities/products/aim-9/aim-9x/index.html>.

¹²⁸ A good example of early ECM being used in combat involved the British' use of chaff (Window) during WWII. Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command* (Toronto, Canada: University of Toronto Press, 2009), 140. A contemporary data point would include the use of electronic jammers in

target's heat signature, to include the sun, hot rocks, and flares.¹²⁹ Adversary maneuvers also impact a missile's Pk. Maneuvers cause missiles to bleed energy or lose track of the target as they steer themselves through the air in relation to optimal intercept profiles.¹³⁰ While a missile's onboard computer may help preserve energy by optimizing course-correction commands, programming the logic to account for every variable associated with an airborne intercept is immensely difficult.¹³¹ Finally, the adversary may have struck first blood. Fighters damaged as a result of receiving enemy fires are often unable to employ missiles effectively, if at all.¹³²

The gun is not at the mercy of the above uncertainties. However, low missile Pk does not mean the gun will be used in combat. While historical accounts support a relatively high Pk for the gun, they also show the use of the gun has waned since its preeminence in Korea.¹³³ In Vietnam, 42 of the USAF's 135 air-to-air kills were the result of the gun.¹³⁴ USN and USMC pilots used the gun for four of their 18 kills.¹³⁵

Operation Allied Force. Tony Mason, "Operation Allied Force, 1999," in *A History of Air Warfare*, ed. John Andreas Olsen (Washington, D.C.: Potomac Books, Inc., 2010), 232. For a description of ECM capabilities, see Molly Moore, "Electronic Warfare Projects Seriously Flawed; Systems Years Behind Schedule, Hundreds of Millions Over Budget," *The Washington Post*, 7 November 1989, <http://search.proquest.com/nationalnewsexpanded/docview/307228966/1366594DB6530A72514/4?accountid=4332>. See also Air Power Australia Web site, <http://www.ausairpower.net/TE-RWR-ECM.html>.

¹²⁹ Kane, interview by author, 2 May 2012.

¹³⁰ Kane, interview by author, 2 May 2012. For historical examples, see effects of maneuvers on missiles in Vietnam. Tactical Fighter Weapons Center, *U.S. and Enemy Air-to-Air Tactics in SEA: Part II*, Project Red Baron II Interim Report 7 (Nellis AFB, NV: USAF Tactical Fighter Weapons Center, July 1972), M-U 42339-15 no. 7, MSFRIC, 13. Information is now declassified.

¹³¹ Kane, interview by author, 2 May 2012.

¹³² Camilletti, multiple interviews by author, March-April 2012

¹³³ Whereas the highest missile Pk in final years of Vietnam hovered around 13 percent, the gun's probability was near 50 percent. Data is from May 1972 through January 1973. Gen William W. Momyer, *Air Power in Three Wars*, ed. Lt Col A.J.C Lavalley and Maj James C. Gaston (Washington, D.C.: Department of the Air Force, 1978), 157.

¹³⁴ There were a total of 137 kills. The two kills that came from the tail-mounted guns in the B-52H were not included above. Additionally, two of the gun kills involved the

Following the conflict, the gun would not be used by US fighter pilots again.¹³⁶ During the Libyan incidents in the 1980s USN fighters relied on missiles to achieve their lethal effects.¹³⁷ The same was the case for US planes in the Persian Gulf War.¹³⁸ Nor was the gun used in the skies over Yugoslavia during Operation Allied Force.¹³⁹

Other countries have experienced the same trend. Of the Israeli pilots' 484 kills during the late 1960s and early 70s, 246 came from the gun.¹⁴⁰ During the latter part of the 1970s and early 80s, the ratio would fall to 10 of 184.¹⁴¹ On the other side of the conflicts, the Syrians used the gun seven times during their 64 opportunities during their first bout with the Israelis and only once in their second.¹⁴² The Egyptian Air Force's experiences mildly told the same tale. Their ratio of gun-to-total

use missiles and the gun. Donald J. McCarthy, Jr., *USAF-F-4 and F-105 Mig Killers of the Vietnam War, 1965-73* (Atglen, PA: Schiffer Publishing Ltd., 2005), 132

¹³⁵ There were a total of 22 kills. However, the five that were against slow maneuvering prop aircraft and attack helicopters were not included in the above total. Additionally, two of the gun kills involved both the use of missiles/rockets and the gun. Roy A. Grossnick, "List of Navy and Marine Corps Shoot Downs."

Appendix 33, <http://www.history.navy.mil/branches/usna1910.htm>.

¹³⁶ This statement is based on gun kills in a maneuvering engagement, not employment against relatively slow-moving targets. USAF A-10 pilots shot down two helicopters with their 30 mm Gatling guns during the Gulf War. Gulf War Air Power Survey, *A Statistical Compendium and Chronology*, 652-654. Open Source Intelligence Web site, "Coalition Air-to-Air Victories in Desert Storm," <http://www.rjlee.org/legacy/>.

¹³⁷ Grossnick, "List of Navy and Marine Corps Shoot Downs Since 1950," 771.

¹³⁸ Grossnick, "List of Navy and Marine Corps Shoot Downs Since 1950," 771. Gulf War Air Power Survey, 652-654.

¹³⁹ Brown, *Debrief*, 187.

¹⁴⁰ Lon Nordeen, *Fighters Over Israel* (New York, NY: Orion Books, 1990), 200-201. See also Air Combat Information Group Web site, "Israeli Air-to-Air Victories July 1967 - September 1973," http://www.acig.org/artman/publish/article_264.shtml. Air Combat Information Group Web site, "Israeli Air-to-Air Victories in 1973," http://www.acig.org/artman/publish/article_268.shtml.

¹⁴¹ Nordeen, *Fighters Over Israel*, 200-201. Of note, on 11 June 1982, 6 of the Israeli's 17 kills were gun kills. Air Combat Information Group Web site, "Israeli Air-to-Air Victories since 1974," http://www.acig.org/artman/publish/article_270.shtml.

¹⁴² During the late 1960s and early 1970s, there were approximately 70 engagements involving Syrian fighters carrying both missiles and a gun. The numbers above are based on engagements in which the weapon used to achieve the kill is known. There were roughly 6 engagements in which the weapon was unknown. In the late 70s and early 80s, there were 27 kills and 1 unknown. Air Combat Information Group Web site, "Syrian Air-to-Air Victories since 1948," http://www.acig.org/artman/publish/article_272.

kills against the Israelis during the Arab-Israeli conflict was 17:71.¹⁴³ A decade later, the ratio fell to 0:2 when the Egyptians engaged Libyan fighters.¹⁴⁴ Other than some minor skirmishes, in which the gun was often used to target slower-moving and less-maneuverable aircraft, there are not many other noteworthy examples of gun employment in modern times.¹⁴⁵

Though the gun has not recently been employed in earnest, this does not mean the gun's utility will follow the same trend in the future. Over the past decade, a weak global economy has brought the "quality-versus-quantity" argument to the forefront of acquisition affairs.¹⁴⁶ Nations around the world have been challenged by the expenses associated with more technologically advanced aircraft. In the case of the US, the buy for the F-22 Raptor was reduced from over 600 aircraft to 186.¹⁴⁷ Unfortunately, as the DOD's future "workhorse" fighter is rolling off the line at a dismal pace, it is likely the F-22 will have to do more with less, should a robust adversary challenge US dominance in the air.¹⁴⁸ As stealth technology enables modern fighters to close with

¹⁴³ Air Combat Information Group Web site, "Egyptian Air-to-Air Victories since 1948," http://www.acig.org/artman/publish/article_271.shtml.

¹⁴⁴ Air Combat Information Group Web site, "Egyptian Air-to-Air Victories since 1948," http://www.acig.org/artman/publish/article_271.shtml.

¹⁴⁵ In the early 1990s, Russian Close Air Support (CAS) aircraft down several attack and gunship helicopters using the gun. Air Combat Information Group Web site, "Russian and Other Air-to-Air Victories since 1991," http://www.acig.org/artman/publish/article_283.shtml.

¹⁴⁶ General Officer (Question and answer session, Maxwell AFB, AL, 26 April 2012).

¹⁴⁷ Steven Pearlstein and Barton Gellman, "Lockheed Wins Huge Jet Contract; Air Force Plans to Buy 650 Stealth Planes at \$100 Million Each," *The Washington Post*, 24 April 1991, <http://search.proquest.com/nationalnewsexpanded/docview/307395532/1366169FFE84F4DEFA6/2?accountid=4332>. US Secretary of Defense Robert M. Gates, "Defense Budget Recommendation Statement" (speech, Arlington, VA, 6 April 2009), <http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1341>.

¹⁴⁸ Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program*, Congressional Research Service Report (Washington, D.C.: Congressional Research Service, 16 February 2012), 19-24.

the enemy while remaining undetected, the future of gun employment looks promising.¹⁴⁹

While the internal gun's effects on *air-to-air* combat have thoroughly been explored, one final variable needs to be mentioned. Since the gun was first attached to a fighter aircraft, the weapon has been used to target adversaries in the air and on the ground. Modern air-to-air guns are very precise weapons that are adaptable to a variety of ground environments.¹⁵⁰ They have been used extensively in interdiction efforts and close air support for ground forces. During the Gulf War in 1991, 67,827 rounds of 20 mm ammunition were expended by US Air Forces Central Command aircraft.¹⁵¹ Most recently, fighter guns have supported USA, USMC, and special operations forces in Iraq and Afghanistan.¹⁵² Currently, even the USAF air-to-air specialists are training to strafe.¹⁵³ Though they have few real-world requirements for

¹⁴⁹ The majority of kills during WWI were against relatively unaware adversaries. Richard P. Hallion, *Rise of the Fighter Aircraft, 1914-1918* (Baltimore, MD: The Nautical & Aviation Publishing Company of America, Inc., 1984), 158. Though the purpose of stealth is not to forego standoff technologies in favor of close-in encounters, stealth technology does allow for the possibility. As the number of US fighters has gone down, the ability to mass effects will depend on fewer aircraft achieving more effects. General Officer (Question and answer session, Maxwell AFB, AL, 26 April 2012). In the case of the F-22, capitalizing on stealth may equate to four to five more kills should the pilot elect to gun "unaware" adversaries with the aircraft's available bullets. Reference footnotes 67 and 68 of this chapter. Currently, F-22 pilots train to balancing the use of missiles versus the gun in order to yield more effects per aircraft. F-22 Squadron and Wing Weapons Officers from Combat Air Forces, Air National Guard, and Reserve organizations, interviews by author, 11-14 April 2012.

¹⁵⁰ "Except for a few scenarios in which modern bomb-related technologies ensure very precise effects, the gun (M61) is a far more discriminant and flexible weapon." Maj Nathan A. Mead (former F-15E Squadron Weapons Officer and Chief of Weapons and Tactics, US Air Forces Central, Al Udeid AB, Qatar), interview by author, 1 May 2012.

¹⁵¹ Gulf War Air Power Survey, 606.

¹⁵² Maj Scott C. Mills (former Chiefs of instructors for A-10 Division, USAF Weapons School), interview by author, 1 May 2012. Maj Mills has been deployed to Iraq and Afghanistan six times. He served as both a Forward Air Controller-Airborne and a Joint Terminal Attack Controller.

¹⁵³ F-15C Weapons Officers, interviews by author, 11-14 April 2012.

doing so, the pilots want to be ready to flex to an alternate mission when called upon.¹⁵⁴

Conclusions

The gun, like the bayonet, is still a valuable asset in a fighter aircraft. Much of the weapon's value is derived from the pilot's lack of faith in standoff technologies, both in quality and quantity. Whereas the projectiles from ships and soldiers' machine guns have demonstrated a high probability of hitting their marks, the same has not been the case with air-to-air missiles. Additionally, while ships carry large amounts of munitions and the soldier is supported by the numerous guns of his comrades, today's fighter pilot is burdened by the limited number of missiles on his aircraft and a smaller fighter force than had been present in times past. Consequently, based on the uncertainties associated with missiles, the gun is warranted.

Of note, however, is a reality that fighter pilots have always been vociferous about the gun in fighters. While much of their logic for the weapon has been sound, there is indeed a psychological reward that has been tied to the practice of gunning an adversary.¹⁵⁵ Though the majority of *today's* fighter pilots would immediately question someone's decision to forego missiles for a gun kill, there are those who would applaud such efforts. Fortunately, pursuing such romantic ideals has not caused leaders to abandon longer-range technologies in support of air superiority; at least not yet.

¹⁵⁴ Fighter aircraft responsible for US homeland defense are charged with using whatever means available to achieve effects on a target. For example, F-15C's may have to strafe maritime vessels with the gun, as air-to-air missiles have limited capabilities against such threats. *F-15C Weapons Officers*, interviews by author, 11-14 April 2012.

¹⁵⁵ Pilots in fighter squadrons today are many times labeled according to their BFM skills. For example, the phrase "He's a good BFMer" is more often heard than "He's a good marksman (referring to one's ability to employ missiles)." *Weapons Officers*, interviews by author, 11-14 April 2012.

Conclusion

This project set out to answer two questions. First, is there value in vestigial close-to-kill technologies? Second, are they cost-effective? Unfortunately, as the weights of costs versus benefits appear to vary with analysis of individual technologies, the answers to these questions are not universal. However, looking at the ram, bayonet, and internal gun, as a whole, there are trends in relation to five major themes that support narrower responses. The themes include: quality of long range technologies, number of standoff effects, likelihood of a close-quarters encounter, expenses of the vestigial technology, and unintended costs and benefits.

Quality of Long Range Technologies

Perhaps the most influential factor related to the value of a vestigial technology is the actual and/or perceived effectiveness of the technology's replacement. Should a standoff weapon prove itself to be both reliable and effective, leaders and operators are likely to favor the technology over more primitive forms. In turn, they are more apt to pursue the technology in earnest.

Of the long range technologies present in the case studies, only the combat vessels' and soldiers' standoff weapons demonstrated a degree of reliability that met the material and psychological needs of both leaders and operators. When it comes to guns on fighter aircraft, the poor historical performance of missiles and their probability for failure in the future weigh heavily on operators' psyches. Consequently, airmen have been less receptive to the removal of the gun than their sea and land-based counterparts.

Available Number of Standoff Effects

Closely tied to the quality of the standoff technology is the number of standoff munitions leaders and operators have at their disposal. There appears to be a loose correlation between the number of long-range

munitions available and the willingness to embrace an uncertainty.¹ Generally speaking, the greater the number of long-range munitions available, the more willing leaders and operators are to forego vestigial technologies; especially when the long-range weapon can also be used in close quarters.

In the case of the combat vessel, the sheer number and variety of effects that ships could deliver probably offset fears associated with being potentially outnumbered in combat. With regard to the soldier, the considerable amount of ammunition an individual carries likely mitigates the threat of an intense firefight. Additionally, should a lone soldier find himself short of ammunition, he finds comfort in being able to rely on those around him for cover and resourcing. However, with the fighter pilot the situation is slightly different. Fighter aircraft do not carry ample numbers of missiles and cannot be resupplied until they have returned to base. Additionally, missiles from supporting aircraft may be short in coming. Consequently, there appears to be less tolerance for abandoning the pilot's primordial killing technology.

Likelihood of a Close Encounter

The third theme relates to the probability of a fight taking place in close quarters. There are psychological emotions associated with thinking an intimate engagement is likely. Imbedded in these emotions are survival and offensive-based instincts that spur the desire for reliable and effective technologies. Accordingly, as close-to-kill technologies are enduring in character and tied to the operator, they tend to be more sought-after when the enemy's potential for fighting in close looms large.

All three of the case studies highlighted a relationship between the perceived likelihood for an intimate encounter and a desire for a close-to-

¹ The available number of long range effects may be perceived in a variety of ways. For example, a leader may evaluate the number of available effects in terms of the total quantity of munitions able to be delivered at any given time. The operator, on the other hand, may view his available effects in terms of what he has immediately at his disposal.

kill weapon. With regard to the ram, the weapon was not the focus of ship design on the open seas. Only in the narrow waterways along the coast of the United States did leaders on both sides of the American Civil War demand the bows of their vessels be readied for the practice. In the case of the bayonet, not knowing when and where an enemy might be encountered increases the appeal of the technology. The same can be said for the fighter pilot. However, rather than being bothered by an enemy hiding in a fox hole or around the corner of a building, he is troubled by the “cover” enemy electronic counter measures provide. Accordingly, he has a natural desire for the gun.

Old Technology's Expenses

The monetary expenses associated with vestigial close-to-kill technologies encompass the fourth theme. Of the many correlations that could be drawn between varying expenses and vestigial technologies, one stands out. The greater the extent to which a vestigial weapon is integrated *into* the technology's platform, the more costly the weapon becomes; as integrating a vestigial technology into a new platform is an expensive proposition.

Again, all three analyses supported this relationship. Incorporating the ram into the ship required a number of expensive design modifications. As the costs for building combat vessels grew, so did the costs of adding rams. The expenses associated with reinforcing a vessel's entire structure likely factored into its absence from future designs. The bayonet highlighted the opposite end of the spectrum. Whereas the ram was a part of the vessel, the bayonet depended on a simple attachment point that could be integrated into future firearms at low cost. As the expense of the bayonet lug likely did not enter into leader's calculations, they were more apt to include the device on modern rifles. Though the fractional expense associated with the internal gun lie somewhere between the ram and the bayonet, they trend in the direction of the former. However, as the gun's presence isn't tied to the majority of

the aircraft's structure and systems, its expense appears less prohibitive than its naval equivalent.

Unintended Costs and Benefits

The final theme includes the potpourri of factors that contribute to the valuation of a close-to-kill technology. Unintended costs and benefits surface in light of second and third-order effects. While the linkages derived from these effects are often less defined than those already mentioned, they are no less relevant. Two such linkages are present in the analyses of the ram, bayonet, and internal gun. First, as close-to-kill technologies demand the highest levels of mental and physical agility, they tend to improve performance in other areas; ranging from preparing for combat to unit morale. Two of the three case studies specifically highlighted random benefits derived from the intense character of an intimate engagement. Bayonet training readies soldiers' psyches for killing at large. Training to the gun helps pilots in recognizing missile employment zones.

The second trend is less straightforward. It appears that close-to-kill technologies are often well suited for alternative purposes. In all three case studies, the weapons yielded different benefits when they were used in different manners or had been modified in form or function. In the case of the ram, the weapon dutifully served the commercial shipping sector. With regard to the bayonet, several pieces of a soldier's equipment could be replaced with minor changes to the weapon and its scabbard. The internal gun's example is no different. By simply aiming the weapon at the ground and infusing some explosives into the bullets, the weapon is well-matched for the ground mission that led to its inception.

The Takeaway

Answering the questions from the beginning of this chapter is a complex affair. However, addressing the above five themes sheds some light on the value of close-to-kill technologies and their cost effectiveness.

In general, it appears value and cost appraisals depend more on a weapon's capacity to satisfy the psychological and social needs of leaders and operators than meeting material demands. While there are material-based reasons for retaining technologies past their prime, the justifications are not as persuasive as their psycho-social counterparts. Unfortunately, it is often difficult and time-consuming to assess and evaluate the psychological and social needs associated with any technology; in the case of this thesis, far less time was required to research and analyze the material factors relevant to the three technologies. As this condition is likely not going to change in the near future, leaders must be mindful of the complex arguments that inhere in vestigial technologies and give them serious thought before adopting them wholesale or dismissing them out of hand.



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